1. Dale Browne

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Progress Report for NASA
5. Contract NAS9-15476

2. ANALYSIS OF SCANNER DATA FOR CROP INVENTORIES

Program Manager
3. ROBERT HORVATH

Program Area Managers
RICHARD C. CICONE
RICHARD J. KAUTH
WILLIAM A. MALILA

6. 15 FEBRUARY 1981 - 30 JUNE 1981

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16. Abstract

This report summarizes the progress on subject contract during the second quarter and first half of the third quarter of the 1981 contract year. It is comprised of the presentations made at quarterly technical interchange meetings held during the week of July 6, 1981, at NASA/JSC.

17. Key Words	18. Distribution Statement
Crop Inventory, Landsat, Sampling, Temporal Profile Fitting, Machine Labeling, Area Estimation, Through-the-Season Estimation, Small Fields, Argentina	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	vi + 271	

PREFACE

The following report serves as a quarterly report for Contract NAS9-15476 which is entitled "Analysis of Scanner Data for Crop Inventories". This report describes the work carried out under that contract for the period 15 February 1981 - 30 June 1981.

Work on this contract is performed in the Infrared and Optics Division directed by Mr. Richard R. Legault. Mr. Robert Horvath is the Program Manager for this contract.

This contract, performed by the Environmental Research Institute of Michigan (ERIM) for the Space and Life Sciences Directorate of the NASA/Johnson Space Center, is part of the multi-agency AgRISTARS Program and supports both the Supporting Research (SR) and Foreign Commodity Production Forecasting (FCPF) Projects within AgRISTARS. The overall goal of AgRISTARS is to determine the usefulness, cost and extent to which aerospace remote sensing data can be integrated into existing or future U.S. Department of Agriculture (USDA) systems to improve the objectivity, reliability, timeliness and adequacy of information required to carry out USDA missions.

The Environmental Research Institute of Michigan and the Space Sciences Laboratory of the University of California at Berkeley comprise a consortium having responsibility for development of corn/soybeans area estimation procedures for use on data from South America within both the Supporting Research and Foreign Commodity Production Forecasting Projects. Other supporting research activities are also conducted by them.

TABLE OF CONTENTS

MULTISEGMENT CORN-SOYBEAN ESTIMATION

C. Hay - UCB

F. Pont - ERIM

Presented at

SR Quarterly Technical Interchange

July 1981

OBJECTIVE OF PRESENTATION

DESCRIBE THE UPCOMING MULTISEGMENT ACTIVITIES

Outline of Presentation

I. Introduction and Background

II. Dynamic Stratification

III. A Multisegment Extension of the Corn-Soybeans Baseline

IV. Signature Extension (IBM S P-2 and ERIM S P-B continued)

V. Some Questions and Issues as Currently Understood

VI. Plans for Upcoming Quarter

BACKGROUND

(Past Research Related to P-2)

- UCB Study
  - Analyst gives quick proportion estimate, p', for every possible segment
  - Analyst provides best accuracy proportion estimate, $\hat{p}$, for a sample of segments
  - Regress $\hat{p}$ and p' and produce a total area estimate based on regression
- Procedure B in Kansas (ERIM)
  - Across segment clustering
  - Developed procedure for choosing representative training units
  - Extension of training to population
- Multisegment Estimation (IBM)
  - CLASSY clusters
  - Developed procedure for choosing representative training units
  - Extension of training to population

BACKGROUND (Continued)

(Past Research Related to P-2)

- Multisegment Estimation (ERIM)
  - Across segment clustering
  - Data normalization to remove some of between segment variability
  - *Static* strata (UCB's degree days and precipitation strata)
- Cluster Sampling Inefficiency (LARS)
  - Used various sample unit sizes ranging from LACIE segment to single pixels
  - Total number of pixels labelled a constant
  - Measure variance as function of sample unit size
  - Factor of 8 available in sampling efficiency, by labelling isolated pixels

OVERALL CONCLUSIONS FROM PREVIOUS EXPERIENCE

- Regression Techniques Have a Higher Potential for Efficiency Gain Than Multi-segment Stratified Areal Estimation Techniques (UCB, USDA (WIGTON), UCB/CWRB)
- Large (LACIE) Segments Limit Sampling Variance Due to Inefficiency of Cluster Sampling (LARS, JSC)
- Variations in Signatures Limit the Area Over Which Training is Applicable and Therefore Limit the Training Gain Which can be Achieved (Procedure B, IBM P2)
- General LACIE/TY Experience
  - About 3 sample segments/full frame area
  - Sampling variance about equal to measurement variance

CONSTRAINTS ON SAMPLING

I. Computer Constraints Establish an Upper Bound on the Number of Segment*Size Processing

II. Analyst Team Requires 2 Hours/Region Prelabeling

III. Analyst Team Requires 1 Hour/10 Targets Labeling

BASELINE COST ESTIMATE FOR FULL FRAME EQUIVALENT: (3 Segments)

2 Prelabeling Analyst-Units/Segment	
10 Labeling Analyst-Units/Segment	(100 Targets Labeled)
12 Analyst-Units/Segment	
36 Analyst-Units/Full Frame	(300 Targets Labeled)

A MULTISEGMENT COST ESTIMATE FOR FRAME

(4 DYNAMIC STRATA THREE 64x64 SEGMENTS/STRATUM)

2 Prelabeling Analyst-Units/Dynamic Stratum

2 Labeling Analyst-Units/64x64 Segment (20 Targets Labeled)

2+3(2) = 8 Analyst-Units/Dynamic Stratum

32 Analyst-Units/Full Frame (240 Targets Labeled)

A MULTISEGMENT EXTENSION OF THE BASELINE CORN-SOYBEANS PROCEDURE

- Stage 0
  - Sample a Large Number of Smaller Segments (say N_0)
  - Post Stratification
  - Corn/Soybean Discriminant and/or Other Stratum Specific Training for each Stratum
- Stage 1
  - Sample (size $N_1 \leq N_0$, likely $N_1 = N_0$)
  - Obtain Automatic Proportion Estimates for Entire Stage-1 Sample
- Stage 2
  - Allocate N_2 Segments to be Labeled ($N_2 << N_1$)
  - Obtain Intense Proportion Estimates for Sample (say baseline Stage-2 corn-soybeans estimate)
  - Use Regression Techniques to Obtain Relationship Between the Automatic and Intensive Estimates Based on the N Segments with Both Estimates
  - Use Above Relationship to Aggregate the $N_1 - N_2$ Automatic Only and the N_2 Intensive Estimates

REGRESSION ESTIMATES

Model

$$y_{1\alpha} = \bar{Y} + B\,(x_1 - \bar{X}) + \ell_{1\alpha} \quad \text{where}$$

$y_{1\alpha}$ intensive estimate

$\bar{Y}$ overall mean of $y_{1\alpha}$'s

x_1 automatic estimate

$\bar{X}$ overall mean of X_1's

$\ell_{1\alpha}$ i.i.d. random variables with mean 0

Variance $\quad E\ell^2_{1\alpha} = S^2_e = (1 - \rho^2)S^2_y$

Large sample $(n_1 - n_2)$ with only X's

Smaller sample (n_2) with both X_1's and $S_{1\alpha}$'s

REGRESSION ESTIMATES (Continued)

The estimate of $\bar{Y}$ is

$$\bar{y}_{lr} = \bar{y} + b(\bar{x}' - \bar{x}) \quad \text{where}$$

$\bar{y}$ and $\bar{x}$ are the means of y and x from the second sample

$\bar{x}'$ is the mean of x from the first sample

b is the least squares estimate of B obtained from the second sample

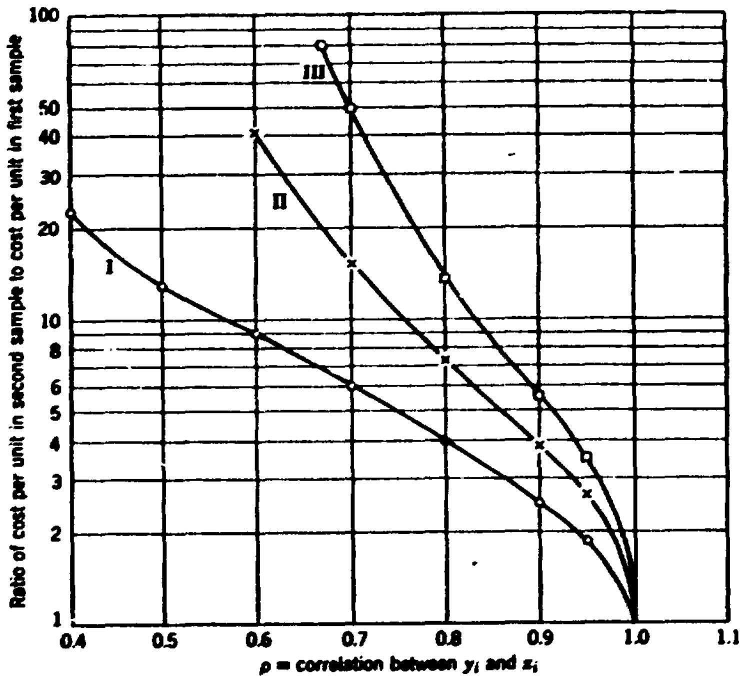


Fig. 12.1 Relation between c_a/c_w and ρ for three fixed values of the relative precision of double and single sampling.

Curve I: double and single sampling equally precise.
Curve II: double sampling gives 25 p:r cent increase in precision.
Curve III: double sampling gives 50 per cent increase in precision.

OTHER REGRESSION ESTIMATES

- Log or Logit Transform of the y_1's and x_1's
- Use of Multiple Independent Variables
- Ratio Estimates
- Interchange of Independent and Dependent Variables

SIGNATURE EXTENSION REVISITED

BASIC ASSUMPTIONS:

(1) The association between spectral classes and crop class is stable with a dynamic stratum

(2) Segments size is large enough to maintain labeling accuracy, and yet there are enough segments to be representative of the variability within a dynamic strata for training purposes

SIGNATURE EXTENSION

- Stage 0 - Choose Large Sample - Post Stratification
- Stage 1 - Cluster Interpretive Units Across Segments Within Dynamic Stratum
  - -- BCLUSTER spectral
  - -- Parameters of profile-fit, or
  - -- CLASSY mode seeking based procedure
- Stage 2 - Allocate and Sample
  - -- Allocate segments to best represent major clusters

    or

  - -- Allocate interpretive units to clusters ignoring segments

ALLOCATION OF SEGMENTS TO LABEL

- Optimal Method is to Choose the Subset Which Best Represents the Spectral Strata by Examining all $\binom{n_1}{n_2}$ Subsets
- Stepwise Segment Selection
- Pairwise Segment Selection
- Factor Analysis Techniques

QUESTIONS/ISSUES

- How Large Will the Dynamic Strata be?

  (How large of a region can signatures be extended)

  CRD size would be nice.

- How Small Can we Make the Sample Units. The Smaller the Better for Sampling but Complications Arise from Measurement and Data Base Considerations

- What is the Best Interpretive Unit?

  - DOT
  - Relocate DOT
  - Blob
  - DOT within blob center
  - Histograms
  - Distributions

PLANS FOR NEXT QUARTER

- Continue Dynamic Stratification Task
- Start Preparation of Full Frame Data
- Investigation of Regression Methods of Obtaining an Estimate from Intensive and Economical Estimates
  - Stage 1 corn-soy with Stage 2 corn-soy
  - Bahdwar's procedure with Stage 2 corn-soy
- Sample Unit Size Investigation
  - Divide segments into 4, 9, or 16 subsegments
  - Decompose the overall variance (corn and soybeans)
    - -- between segments
    - -- between smaller segments within segments
    - -- within smaller segments

REFERENCES

(1) Cohcran, W. G., Sampling Techniques, New York, Wiley, 1963.

(2) Knuth, R. J. and Richardson, W., Final Report, Procedure B: A Multisegment Training Selection and Proportion Estimation Procedure for Processing Landsat Agricultural Data. Report Number (ERIM) 122700-31-F.

(3) Thomas, R. W. and Hay, C. M., Two Phase Sampling for Wheat Acreage Estimation. 1977 Machine Processing of Remotely Sensed Data Symposium.

(4) Thomas, R. W. and Hay C. M., Final Report, Variable Probability Sampling for Acreage Estimation.

THROUGH-THE-SEASON SEPARABILITY OF CORN AND SOYBEANS WITHIN THE U.S. CORN BELT

PROJECT: SUPPORTING RESEARCH

PROJECT ELEMENT: PATTERN RECOGNITION - CORN/SOYBEANS

TASK: THROUGH-THE-SEASON ESTIMATION

PERFORMING ORGANIZATIONS: ERIM/UCB

CONTRIBUTORS: Brian Thelen, Christian Pestre

PRESENTOR: Christian Pestre

July 7, 1981

OBJECTIVES OF OUR RESEARCH

SUPPORT THROUGH-THE-SEASON AREA ESTIMATION FOR CORN AND SOYBEANS

- Understand What, of General Value, Can Come From Landsat in Support of Through-the-Season EStimation
- Develop Corresponding Landsat Information Extraction Technology

OBJECTIVES OF THIS PRESENTATION

Report Progress and Our Current Understanding of the Separability of Corn and Soybeans During the Growing Season in the U.S. Corn Belt

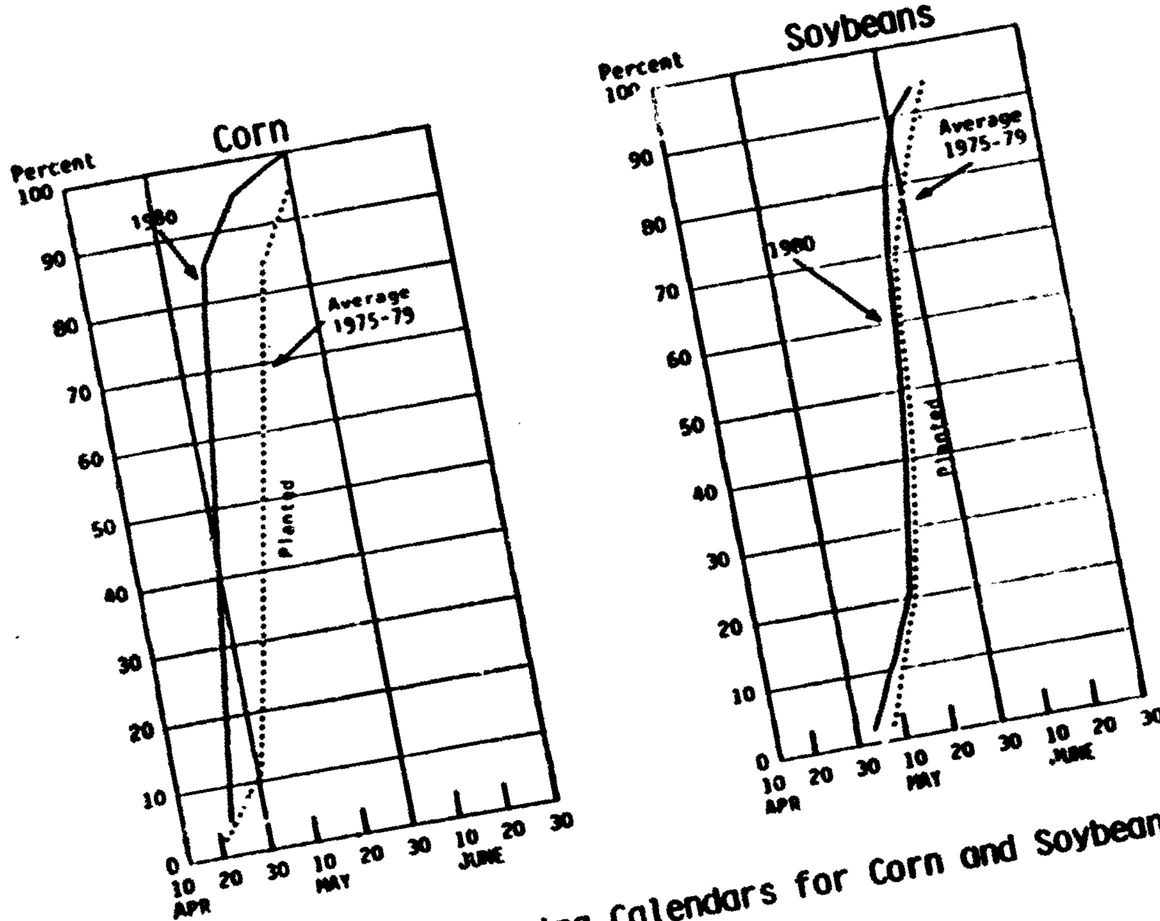
CURRENT RESEARCH EMPHASIS

OUR CURRENT RESEARCH IS DIRECTED AT EXTRACTING INFORMATION RESIDING IN THE FOLLOWING DOMAINS:

- Planting Calendar
- Spectral Characteristics of Crops
- Crop Rotations

1. Planting Calendar

Crop Calendar
Observed in Iowa
1975-79 Average
and 1980

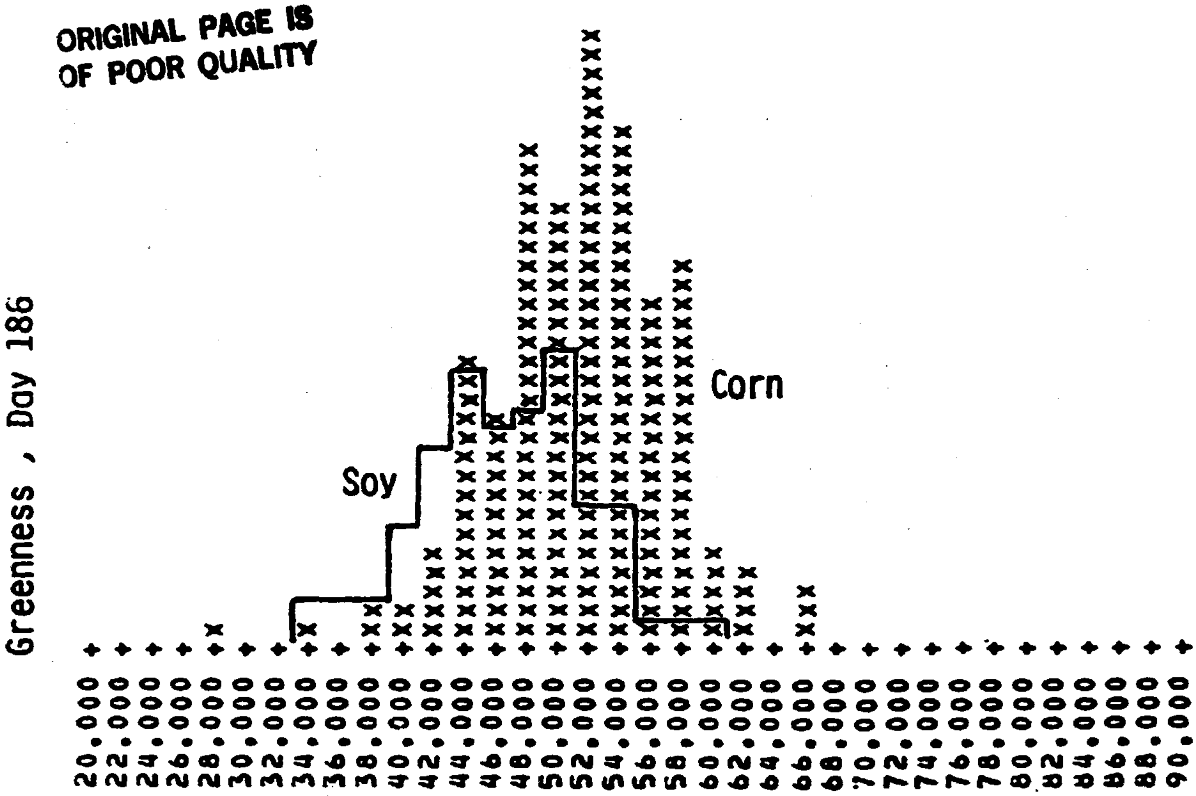


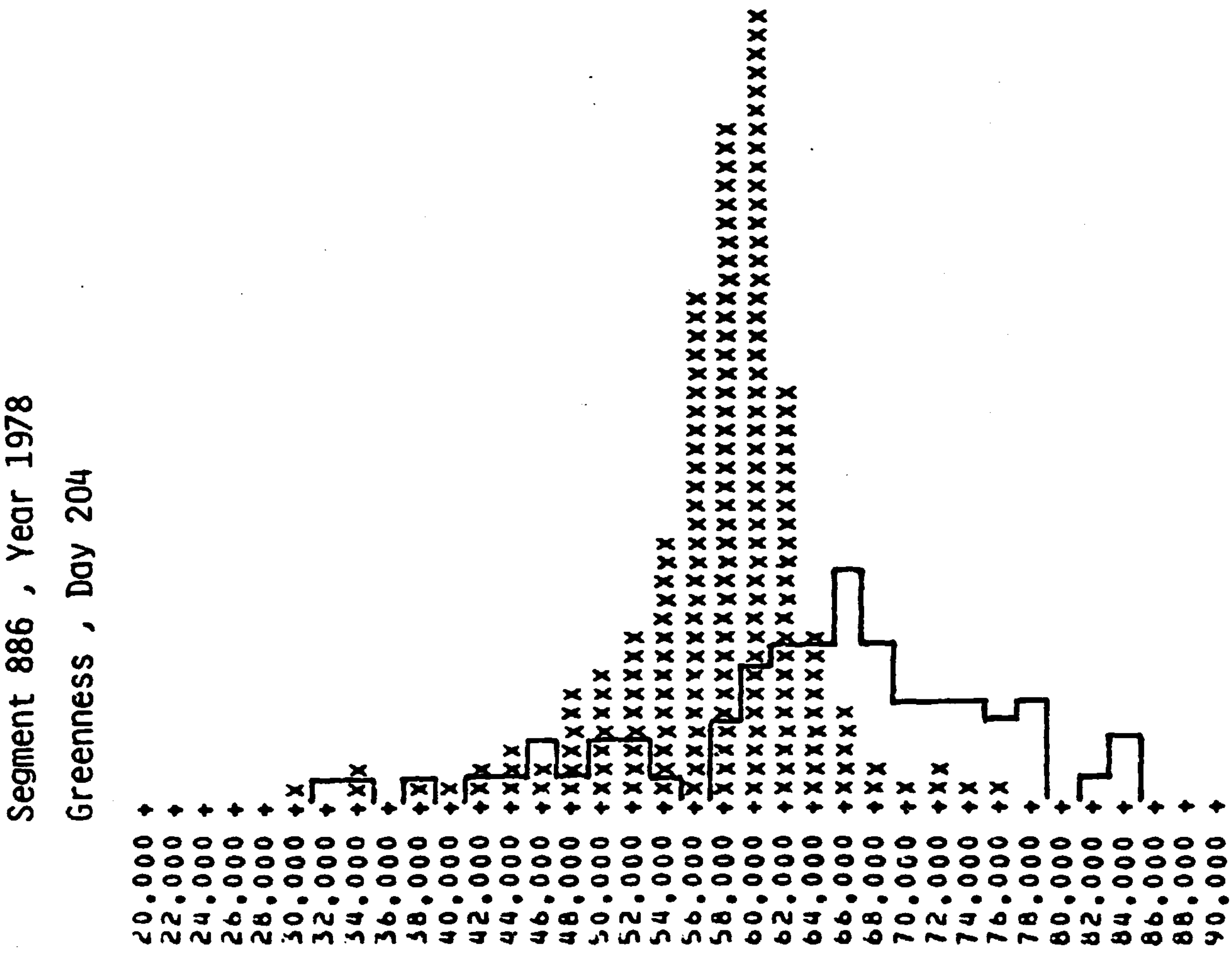
There is Information Residing in the Difference of Planting Calendars for Corn and Soybeans,
Even in the U.S. Corn Belt

- Planting Starts Earlier for Corn
- Planting Ends Later for Soybeans

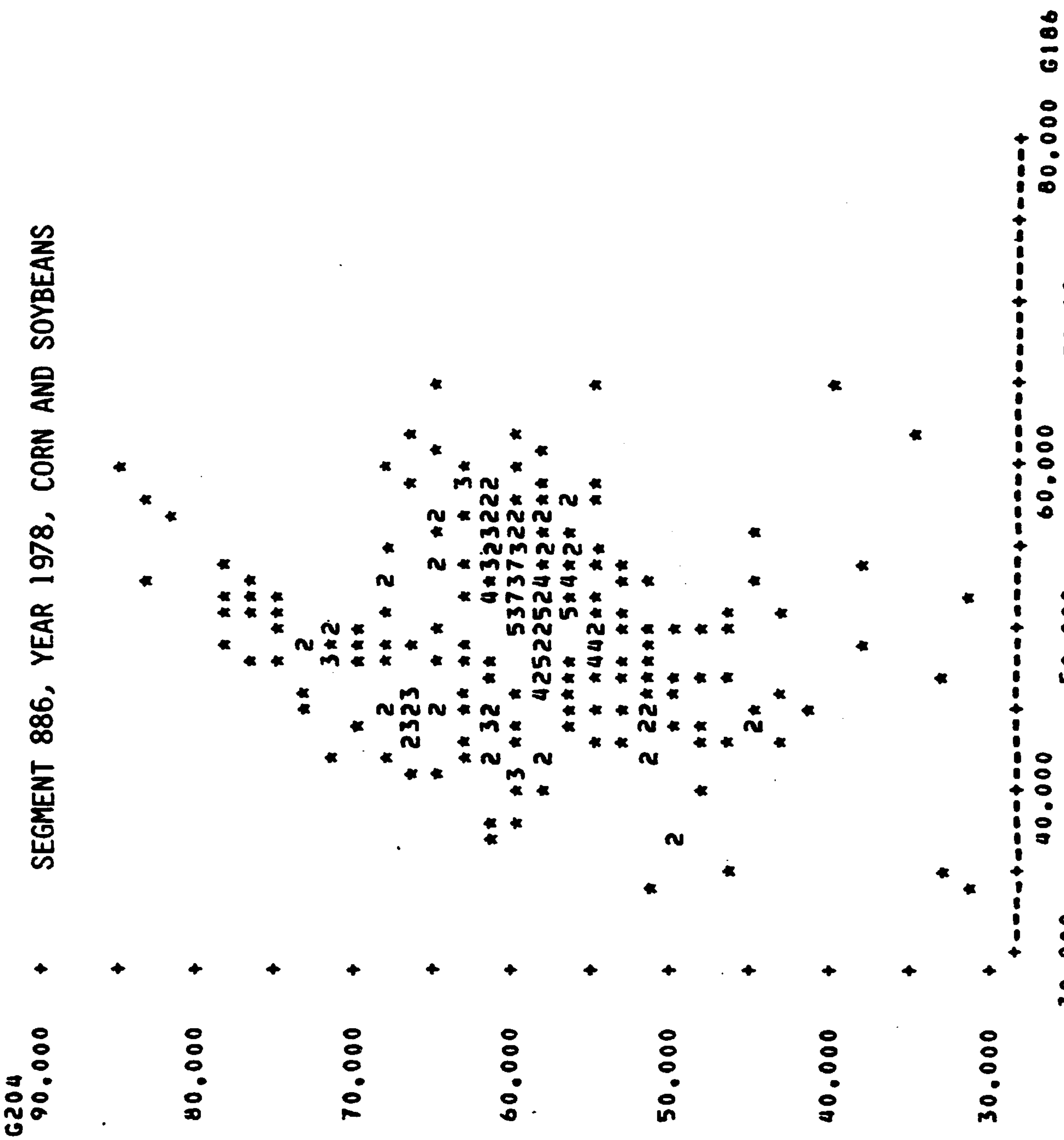
2. Spectral Characteristics of Crops

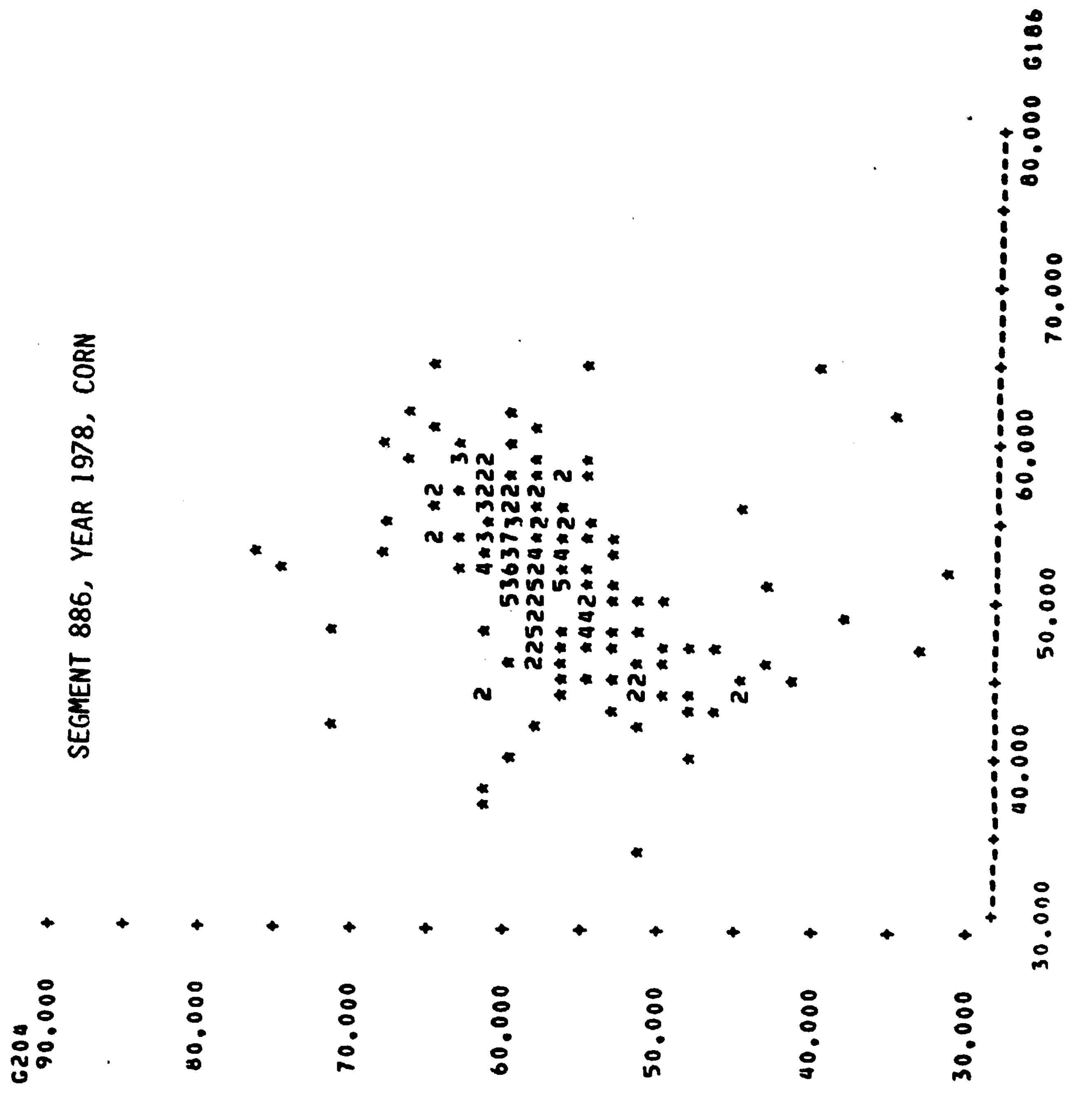
- To Separate Corn and Soybeans, Baseline Procedure Uses Threshold on Single Acquisitions From Separation Biowindow
- Histograms of Greenness of Corn and Soybeans at Different Dates Before Separation Biowindow Suggest Separability Using Correlation Between Two Acquisitions
- Approximate Knowledge of Expected Profile for Corn and Soybeans Indicates How to Interpret Scatter Plot G2 vs. G1
  - can be used for spectral stratification
  - can be used for placing discriminant
- Separability Is Very Dependent on Acquisition History

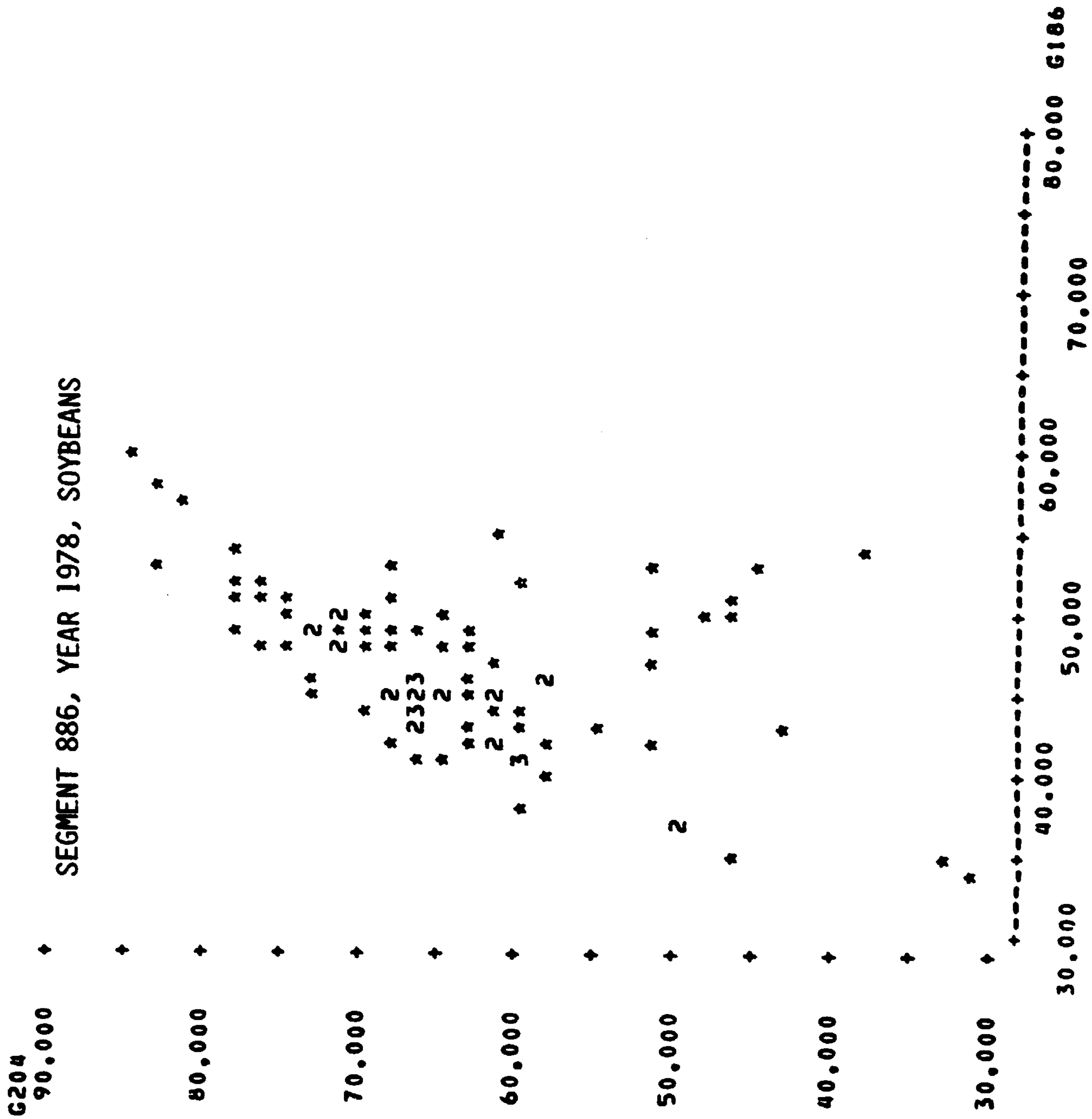

Greenness , Day 186
Soy
Corn


Segment 886 , Year 1978
Greenness , Day 204

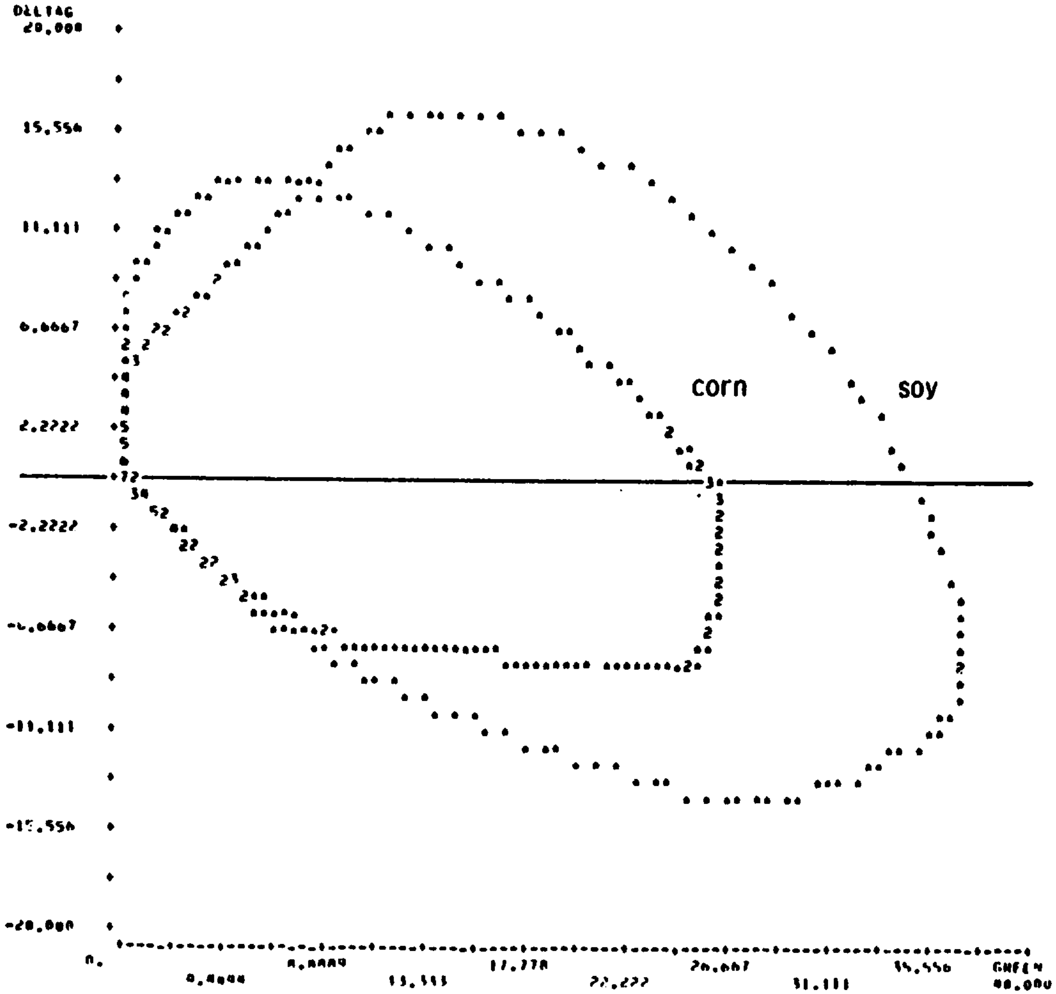
SEGMENT 886, YEAR 1978, CORN AND SOYBEANS




SEGMENT 886, YEAR 1978, CORN
G204
90.000
80.000
70.000
60.000
50.000
40.000
30.000
30.000
40.000
50.000
60.000
70.000
80.000
G186


SEGMENT 886, YEAR 1978, SOYBEANS
G204
90.000
80.000
70.000
60.000
50.000
40.000
30.000
G186
30.000
40.000
50.000
60.000
70.000
80.000

18-DAY INCREASE IN GREENNESS, AS A FUNCTION OF INITIAL GREENNESS (NORTHERN GREAT PLAINS)



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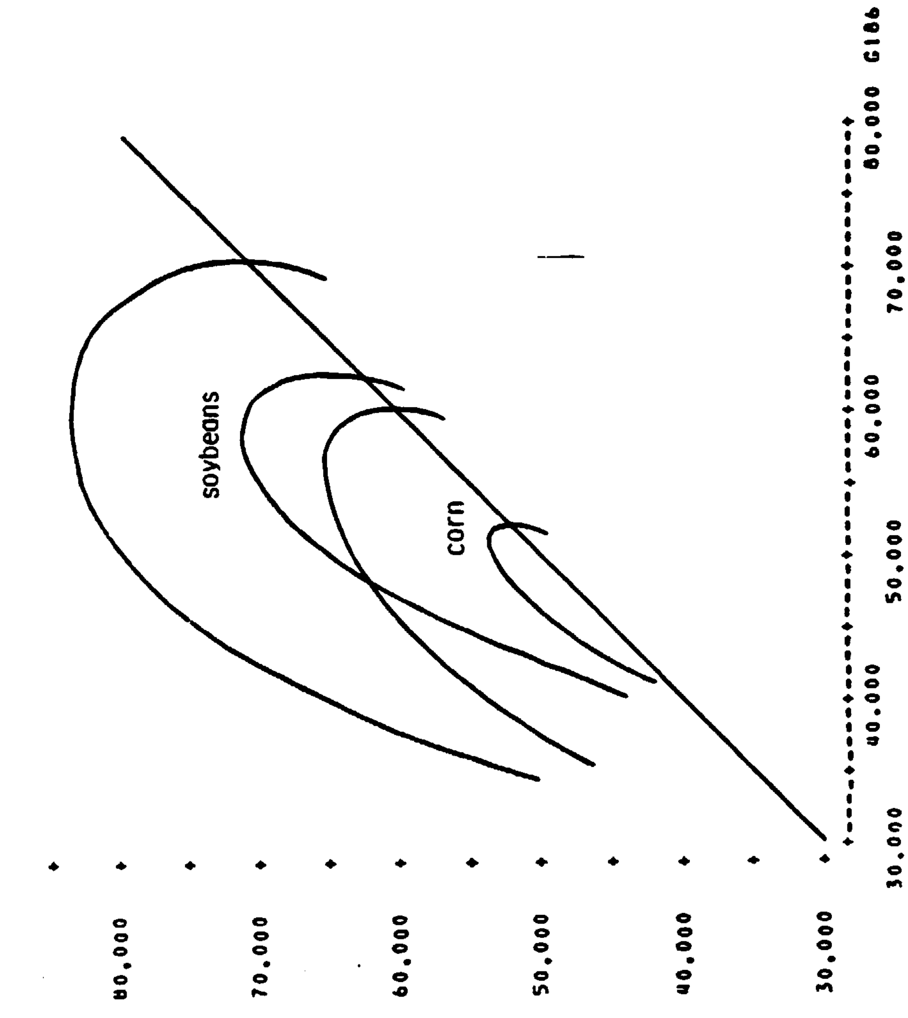


INTERPRETATION DIAGRAM OF SCATTER PLOT G1 vs. G2

3. Crop Rotations

- Yearly Rotations: Some Soybeans are Double-Cropped
- Year-to-Year Rotations: Soybeans Followed by Soybeans is an Infrequent Rotation in the U.S. Corn Belt (Fertilizers, Soil Conservation)
  - examples:

    on segment 886, 5% of soy in 1979 was preceded by soy in 1978
    on segment 883, 8% of soy in 1979 was preceded by soy in 1978
  - potential use for labeling or at least stratification of targets
  - could be analyzed and represented mathematically (e.g., as a Markovian process)

NATURE OF INFORMATION FOR DIFFERENT LABELING FEATURES

Feature Domain	Information	Phenomenon
SPECTRAL PROFILE	OBSERVE	CROP
PLANTING DATE	OBSERVE	CROPPING PRACTICE
CROP ROTATIONS	PREDICT	CROPPING PRACTICE

CONCLUDING REMARKS

- On a Segment, Labels of Different Targets May Come from Different Criteria, Some of Which are Very Specific to Studied Area (Crop Calendar, Crop Rotations)

- At a Given Date, Separability is Very Dependent on Available Acquisitions and May Vary Much from Segment to Segment

CRITICAL TECHNICAL ISSUES RELATED TO TTS ESTIMATION

Presented by: Brian Thelen

During: Pattern Recognition Workshop

Friday, July 10, 1981

CRITICAL TECHNICAL ISSUES RELATED TO TTS ESTIMATION

- The Best Use of Landsat in an All-Source Estimation Procedure
- Classification Targets
  - Pixels, quasi-fields, distributions, or other
  - May change through-the-season
  - Multiyear may provide spatial-spectral clusters even in early season
- Spectral Discrimination of Crops and Crop Groups TTS
  - Specifically corn vs. soy
  - Summer crops vs. winter small grains vs. spring small grains
  - Region specific
- Incorporation of Meteorologically Driven Crop Growth Models for Corn and Soybeans for Use in Spectral Discrimination
- Understanding of Farming Practices and its Use to Enhance Spectral Discrimination
  - Merging in crop planting models
  - Use of crop rotations (multiyear)
  - Field size and shape
  - Detection and adaptation of unusual farming practices

CRITICAL TECHNICAL ISSUES RELATED TO TTS ESTIMATION

(Continued)

- TTS Crop Estimation Must be Done Over Widely Varying Configuration of Acquisition History, Meteorological Conditions and Cropping Practices of Farmers
  - Data set does not cover spectrum of likely configurations to be encountered. Simulation capability for generating synthetic crop spectral data would be extremely useful
- Multisegment TTS Estimation
  - Use of "good" segments to increase accuracy of bad segments
  - Stratification, sampling, and aggregation. (There will multiple stratum/segment estimates of widely varying accuracies. This may be function of that time of season which is deemed most important by the user for having an accuracy estimate.)
- Optimal Use of Multiyear
  - Rotation design of classification targets
  - Rotation design of segments
- Adaptability of TTS Techniques to Many Different Regions
  - Will need to be fine tuned to any region of interest to insure maximal extraction of information

INTERFACES AND/OR REQUIREMENTS BETWEEN MULTIYEAR AND TTS RESEARCH

MULTIYEAR APPROACH

- Optimal Rotation Design for Segments in Light of Increased Segment Estimation Accuracy Due to Multiyear vs. Increased Stratum Level Estimation Accuracy (Sielkens multiyear model)
- Rotation Designs on Quasi-Fields
- Change Detection and Its Use in Adapting Structure of TTS Estimation
- Dynamic Stratification, Sampling and Aggregation
  - TTS estimation is regionally fine tuned
- Prediction of Estimation Accuracy Given Landsat Data, Meteorological Conditions and Acquisition History
- Adaptation of TTS Estimation to Findings of Multiyear Landsat Data

DETAILED PRESENTATION OF ARGENTINA FIELD DATA

Abstract

During the latter half of February 1981, a team consisting of David Hicks, Buzz Sellman, and Gene Thomas of ERIM, and Ed Sheffner and Byron Wood of UCB, traveled to Argentina to make initial observations about agriculture in the corn, soybean and wheat growing regions of the country. Meetings were held with officials in government agencies and with their cooperation and support, fourteen segments were visited so that crop identifications could be made in specific fields and assorted agronomic practices and conditions could be observed by the team.

The results of that ground truth mission, together with field gathered data, will be discussed in the scheduled session. Annotated Landsat images summarizing the crop types observed will be displayed together with the 35mm slides taken in each segment. In addition, several copies of the draft final report covering the Argentina field trip will be circulated for comment. Initial conclusions about agriculture in Argentina will be presented and an open-ended discussion is planned so that comments about future ground truth missions can be proposed.

Note: This material was presented in a special three-hour seminar on July 8, 1981.

TECHNICAL INSIGHTS DERIVED FROM THE BASELINE

CORN AND SOYBEAN PROCEDURE

ERIM/UCB FCPF Corn and Soybean Consortium

Presented by: M. Metzler

Presented at

Supporting Research Quarterly Technical Interchange

July 1981

BACKGROUND

- A STRATIFIED AREAL ESTIMATION TECHNIQUE USING FIELD-LIKE LABELING TARGETS WAS PROCEDURALIZED FOR THE FCPF FY81 CORN AND SOYBEAN PILOT EXPERIMENT IN THE U.S. CORN BELT.
- A TWO PART PILOT WAS DESIGNED; THE FIRST PART WAS TO EVALUATE THE TECHNIQUE OVER 1978 AND 1979 SEGMENT DATA IN AN EXPLORATORY TYPE OF ENVIRONMENT; THE SECOND PART WAS DESIGNED TO DEMONSTRATE AN ACREAGE AGGREGATION OVER A THREE STATE AREA WITH 1980 SEGMENT DATA.
- EARLY RESULTS OF PART 1 POINT TO THE NECESSITY FOR MODIFICATIONS TO CORRECT A TENDENCY TO OVERESTIMATE CORN AND UNDERESTIMATE SOYBEAN.

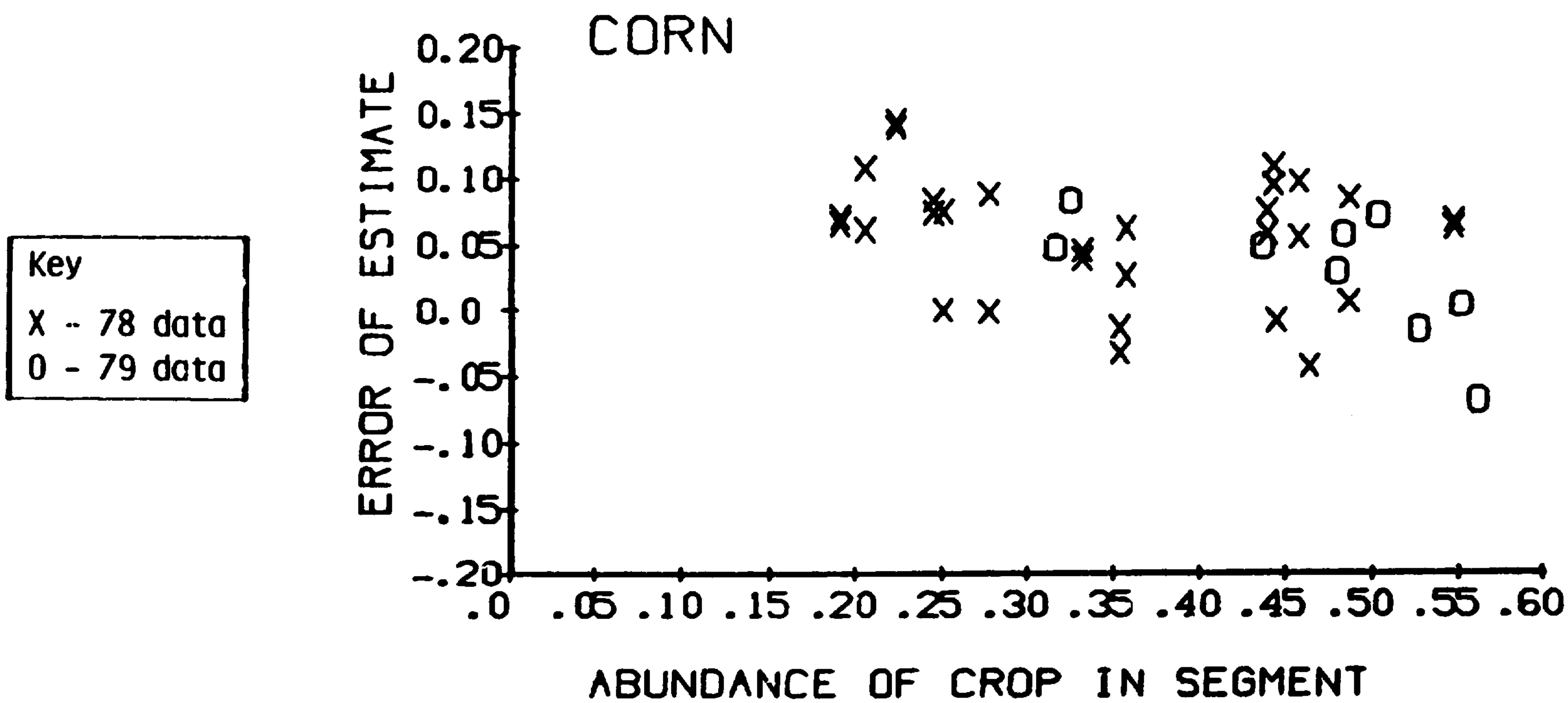
PURPOSE OF PRESENTATION TO SR

- TO ILLUSTRATE CURRENT PERFORMANCE LEVELS OF THE BASELINE PROCEDURE.
- TO DISCUSS TECHNICAL CONCERNS ARISING FROM ANALYSIS OF ERROR SOURCES, e.g., THAT IS, MISREGISTRATION, SENSOR RESOLUTION AND STRESSED CONDITIONS AFFECT SOY PIXELS SUCH THAT THEY ARE NEITHER REPRESENTED BY 'SUPER PURES' NOR SPECTRALLY SEPARABLE FROM CORN AND OTHER CLASSES.

C/S BASELINE ESTIMATION APPROACH

	BIG BLOB INTERIORS (40%)	BIG BLOB BOUNDARIES (40%)	LITTLE BLOBS (20%)
MACHINE:	UNBIASED SAMPLE	SPECTRAL/SPATIAL LABEL EXTENSION	SPECTRAL PROPORTION EXTENSION
ANALYST:	LABEL	--	--

ERROR* OF ESTIMATE FROM ALL AVAILABLE PROCESSING



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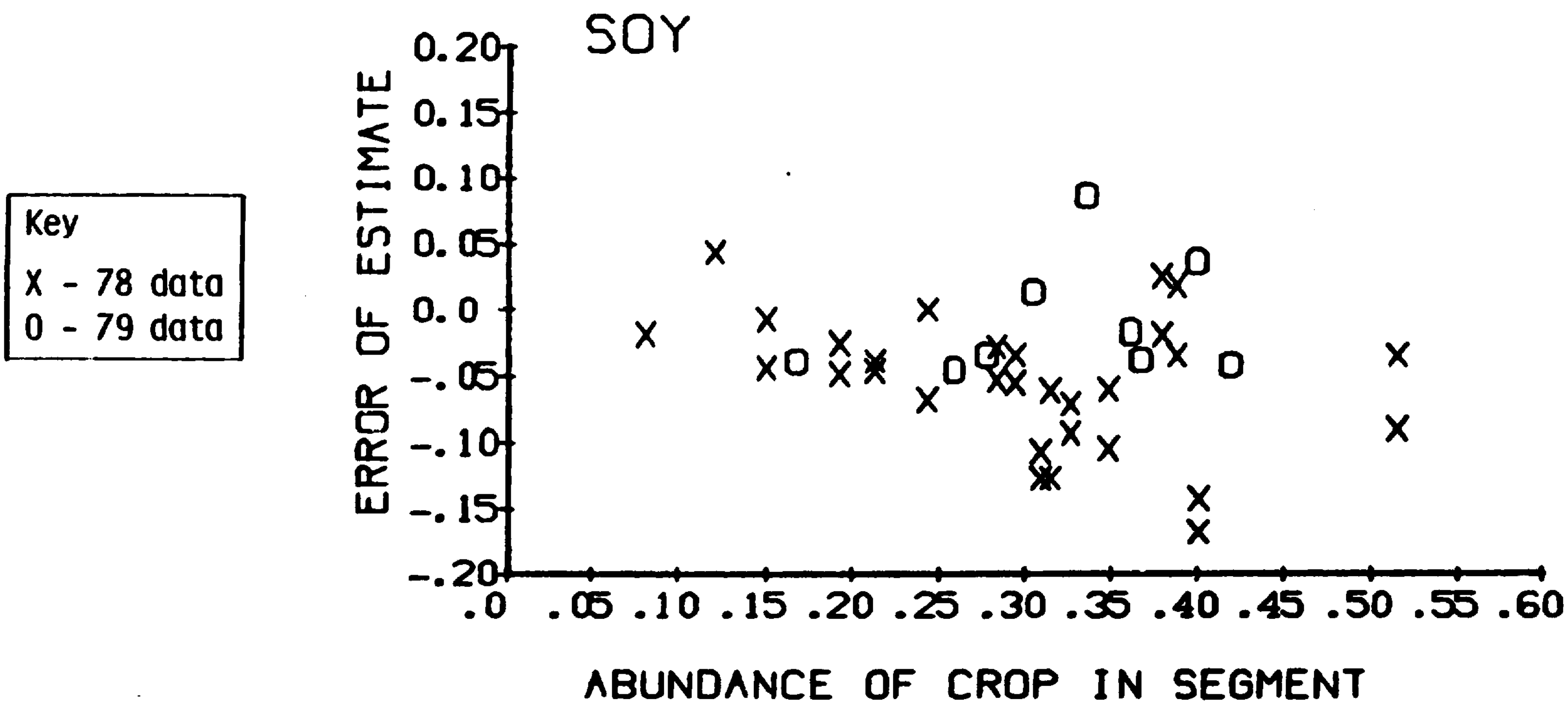
ERROR* OF ESTIMATE FROM ALL AVAILABLE PROCESSING



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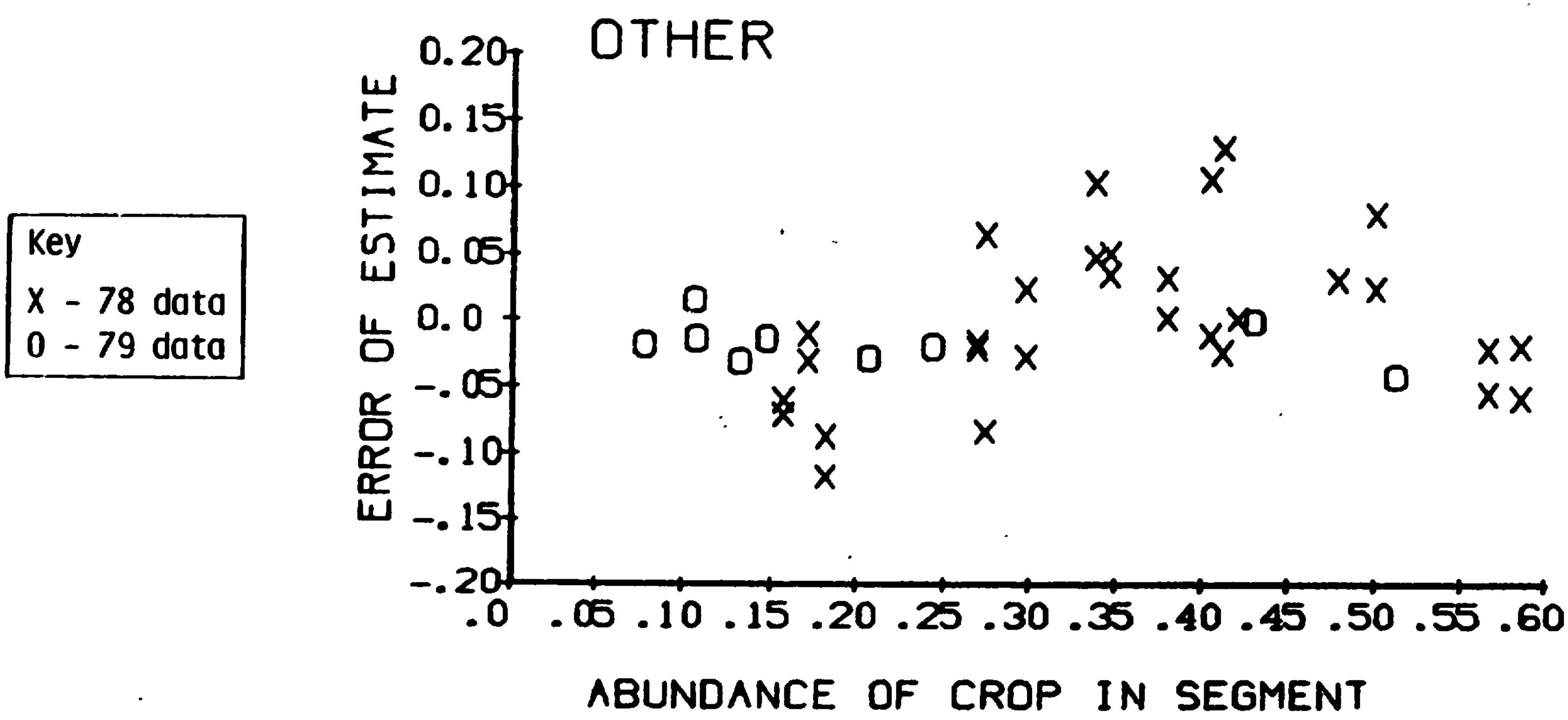

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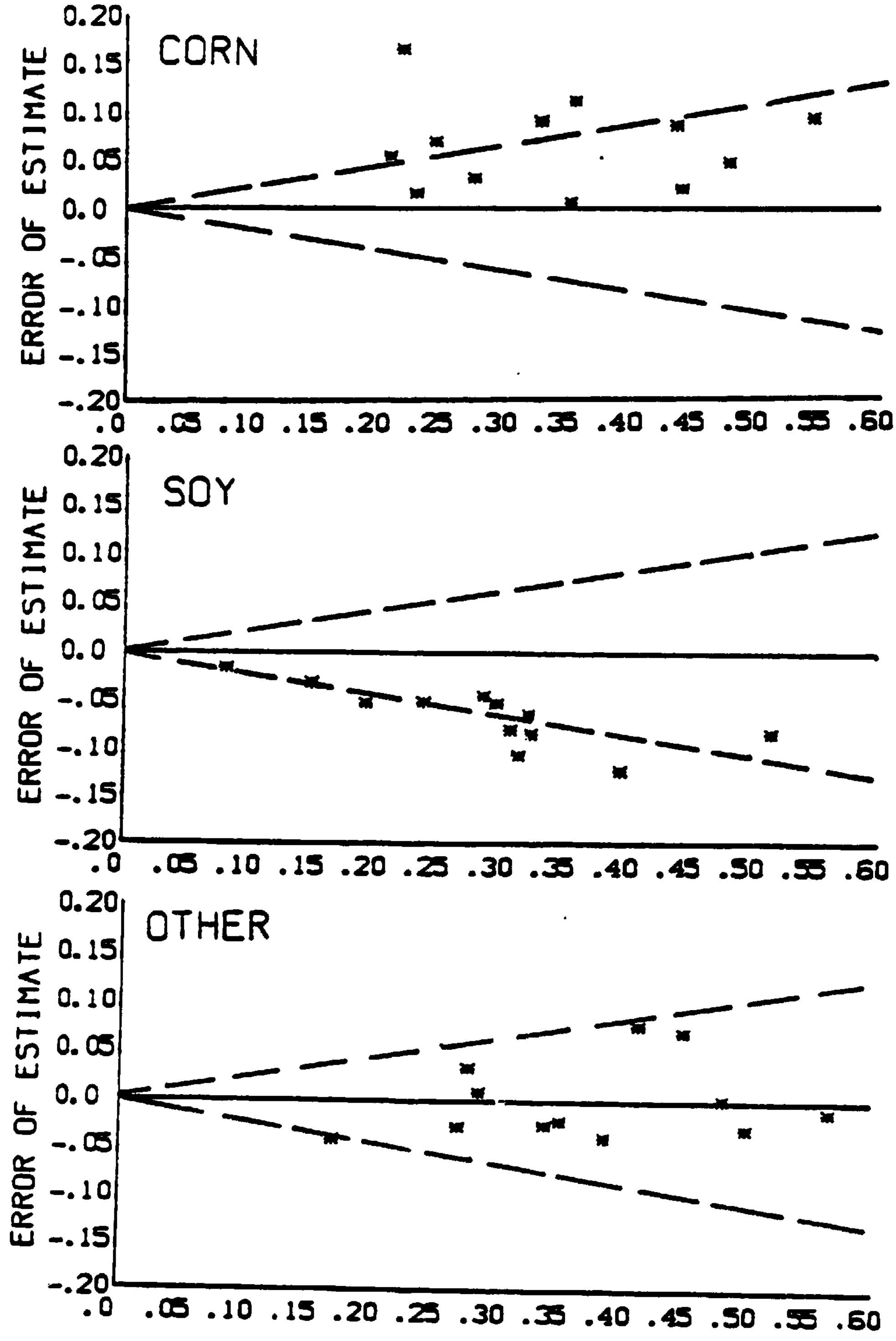
ERROR* OF ESTIMATE FROM ONE ANALYST TEAM



*Unknown GT ignored in determining true P

C/S BASELINE LABELING ACCURACY

BLOB $\geq$ 5/6 Pure (830 of 1,112)

Pixel x Pixel Accuracy

11 Segments

		Label		
		C	S	0
GT	C	95.86	0.39	3.75
	S	4.13	87.50	8.29
	0	6.95	0.84	92.20

KEY SOURCES OF ERROR BY RANK

Corn

1. Labeling of mixed targets
2. 'Enlarged' targets
3. Labeling of pure targets

Soybean

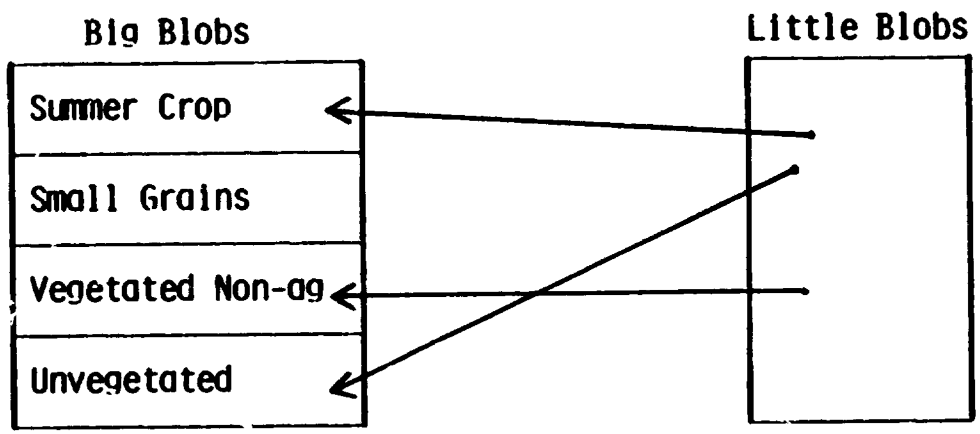
1. Labeling of mixed targets
2. Labeling of pure targets
3. Unsampled Stratum

Other

1. Labeling of mixed targets
2. Labeling of pure targets

: Driven by labeling performance

BASELINE CORRECTION FOR UNSAMPLED STRATUM



Assign Little Blobs to Crop Group Stratum According to Their Temporal Vegetated/Non-Vegetated Pattern; i.e., 'Classify' the Little Blobs Into Crop Groups.

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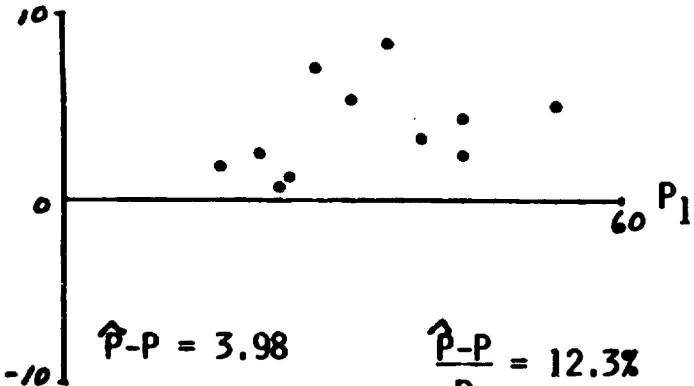
PERFORMANCE OF BASELINE PROCEDURE CORRECTION
USING GROUND TRUTH W/O SAMPLING

No Correction

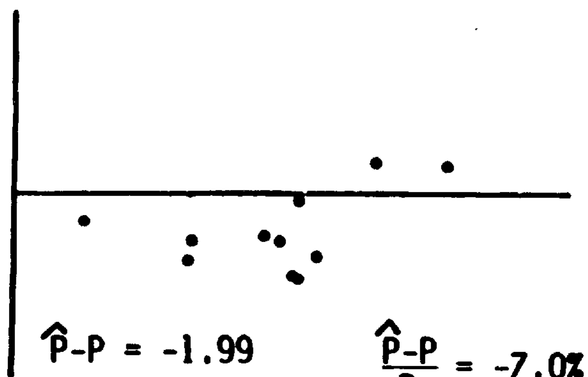
Corn



$\hat{P}-P = 3.98$ $\quad \frac{\hat{P}-P}{P} = 12.3\%$

$\sigma = 2.67$

Soy

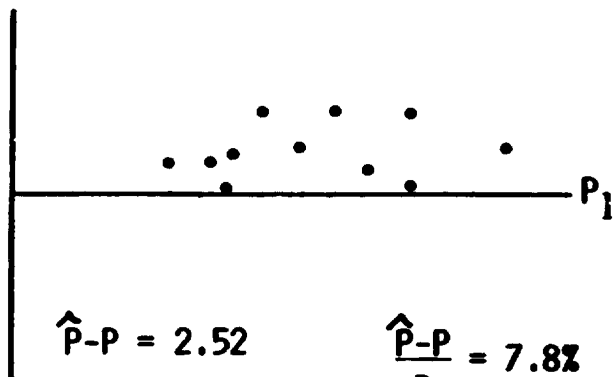


$\hat{P}-P = -1.99$ $\quad \frac{\hat{P}-P}{P} = -7.0\%$

$\sigma = 2.25$

With Correction

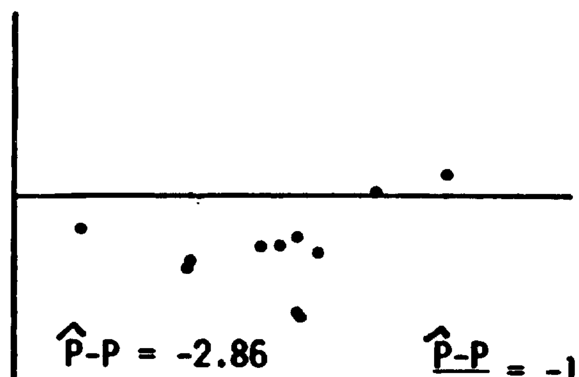
Corn



$\hat{P}-P = 2.52$ $\quad \frac{\hat{P}-P}{P} = 7.8\%$

$\sigma = 1.59$

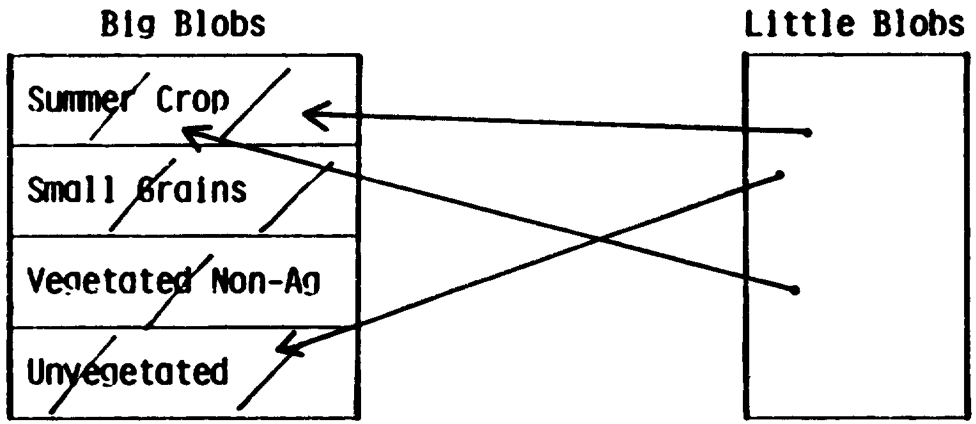
Soy



$\hat{P}-P = -2.86$ $\quad \frac{\hat{P}-P}{P} = -10.1\%$

$\sigma = 2.35$

MODIFICATION #1 TO BASELINE CORRECTION FOR UNSAMPLED STRATUM*



Assign Little Blobs to Crop Group Stratum, and Then Spectrally to Specific Clusters Within Crop Group Stratum, i.e., 'Classify' the Little Blobs into Clusters

*This modification has been implemented.

COMPARISON OF BASELINE AND MODIFICATION WITH GROUND TRUTH

	Baseline		Modification		Modification w/o Edge Bias	
	Error	Std. Dev.	Error	Std. Dev.	Error	Std. Dev.
Corn	2.52	1.59	1.40	1.25	0.44	
Soy	-2.86	2.35	-0.65	0.95	-0.53	
Other	0.34	2.03	-0.75	1.47	0.99	

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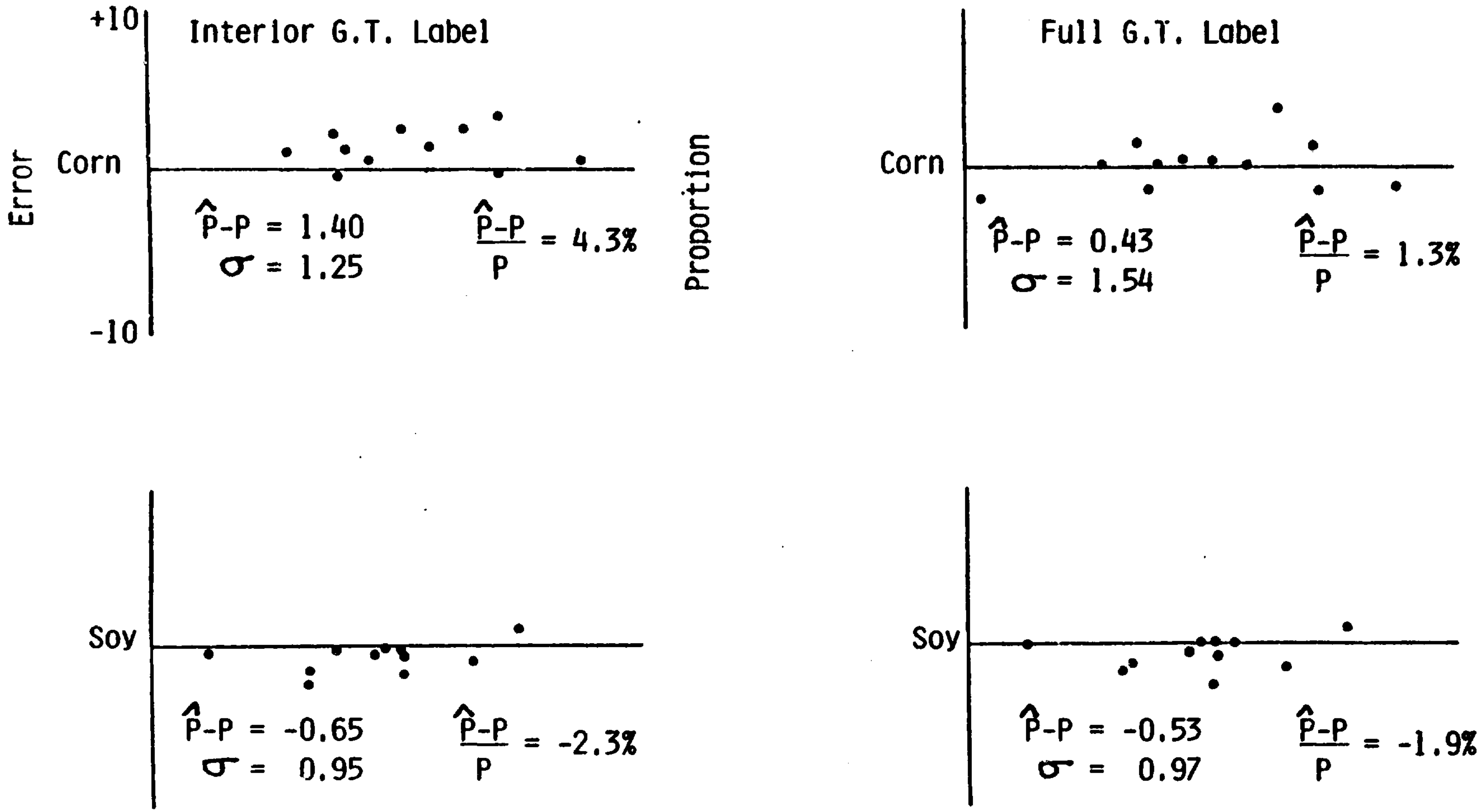
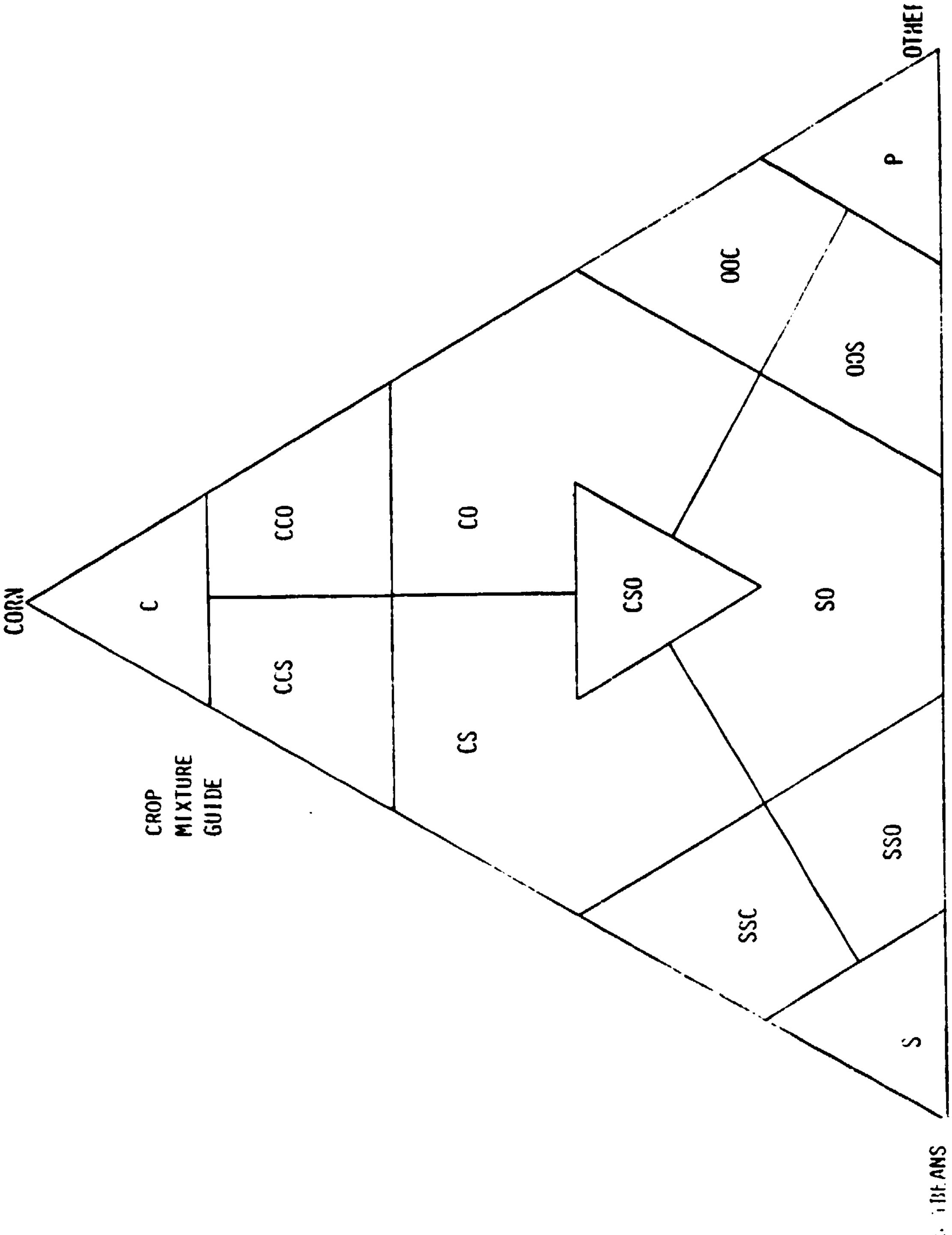
EFFECT OF EDGE BIAS IN BLOBING




CORN
CROP
MIXTURE
GUIDE
C
CCO
CCS
CO
CS
CSO
SO
OOC
SOO
P
SSO
SSC
S

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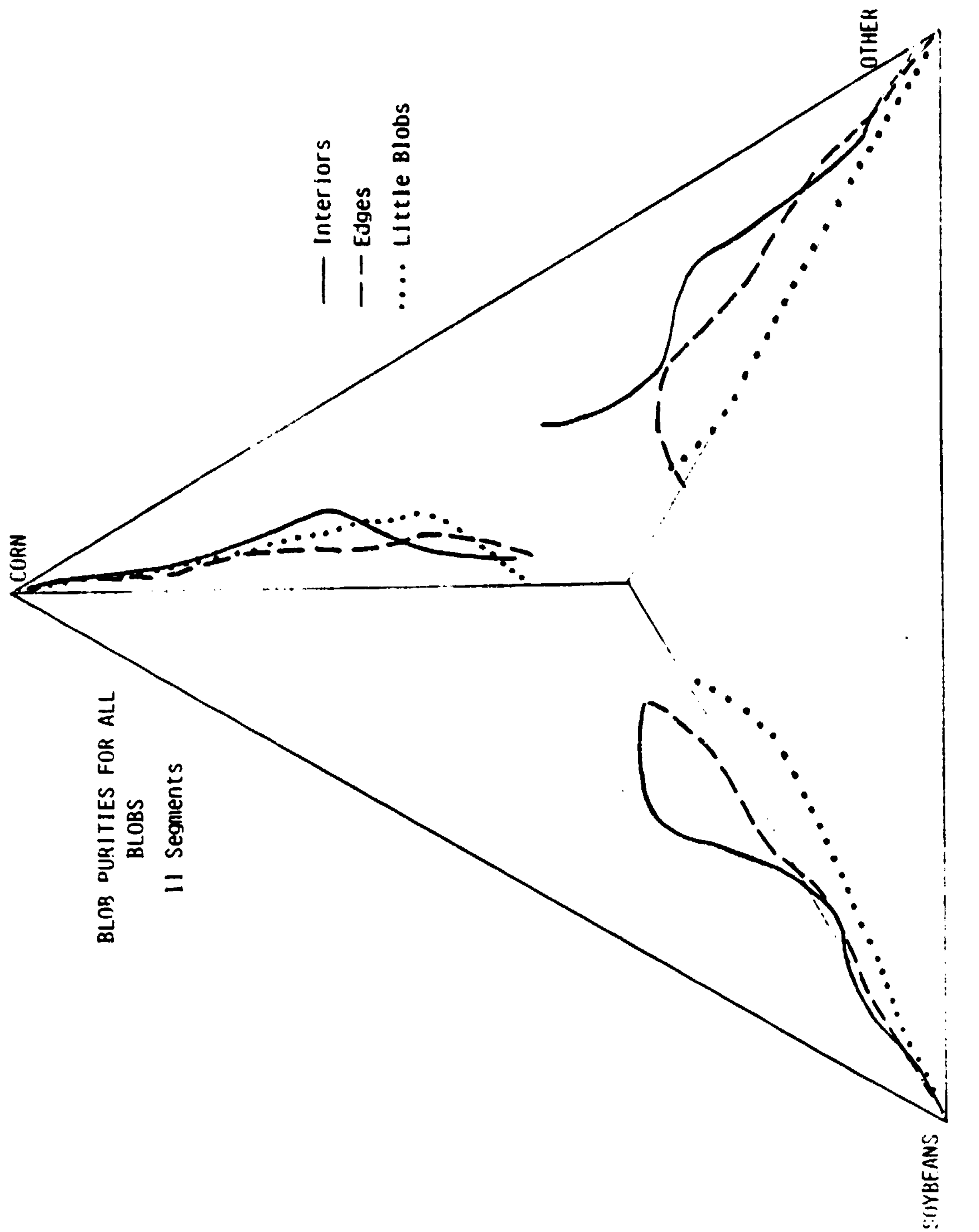
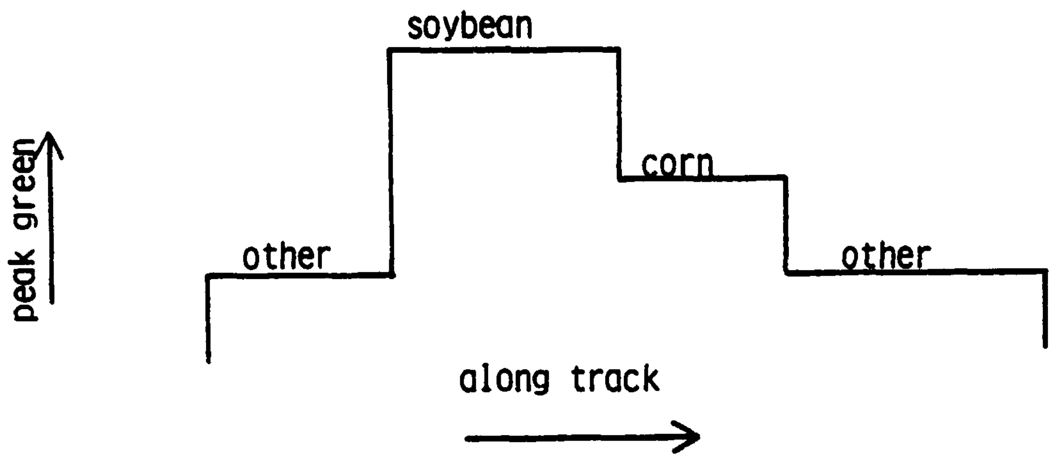
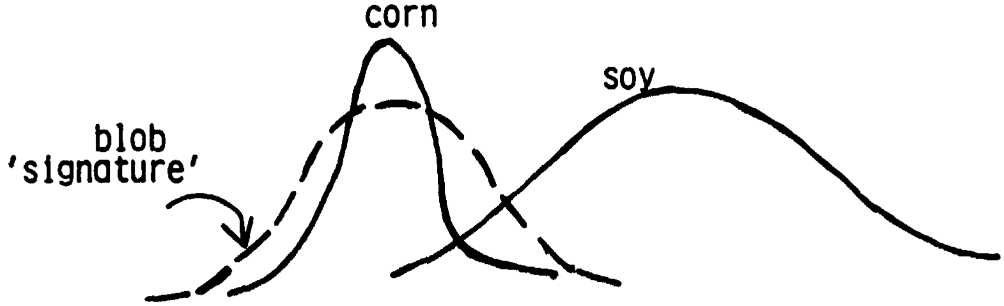


EXPLANATION OF EDGE BIAS IN BLOBING

1. Spectral Relationship Among Crops

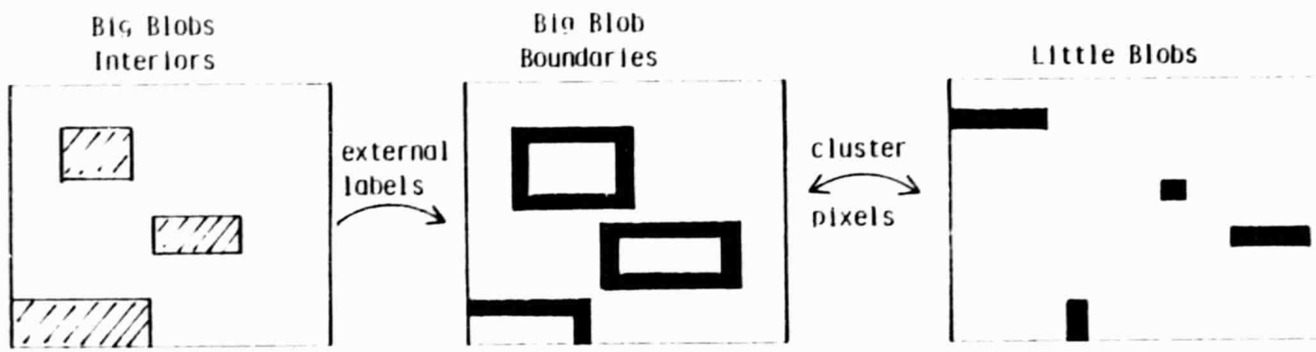


2. Variance Characteristics of Crops



MODIFICATION #2 TO BASELINE CORRECTION FOR

UNSAMPLED STRATUM*



1. Sample, label and produce a S.A.E. for big blob interiors
2. Extend interior label to boundary
3. Cluster big blob boundary pixels
4. Assign little blob pixels to clusters formed in 3, thereby 'classifying' little blobs
5. Produce a composite estimate (weighted average of 1 and 4)

*This modification has not been implemented, but is being researched.

MODIFICATION #2 PERFORMANCE AS A FUNCTION OF
DEFINTION OF LITTLE BLOBS

	Error			
	Definition of Little Blobs			
	<1 Pixels	<2 Pixels	<3 Pixels	<4 Pixels
Corn	0.45	0.95	1.37	1.77
Sov	-0.90	-1.01	-1.19	-1.37
Other	0.45	.06	-0.18	-0.40

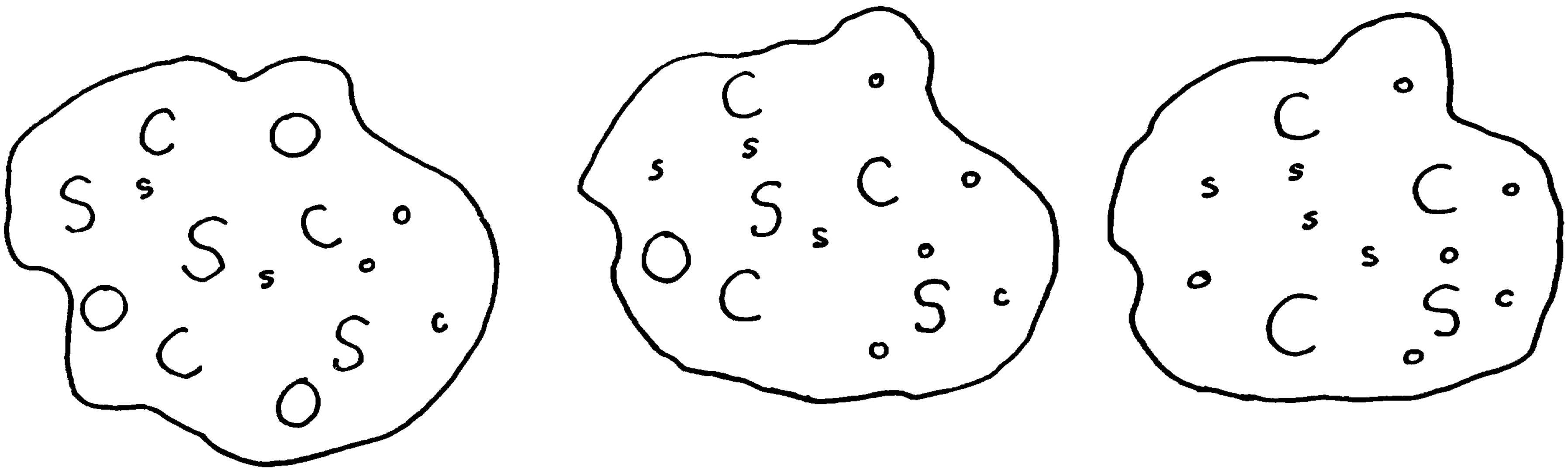
HYPOTHETICAL EXPLANATION

- Smaller Blobs are Dominated by Soy and Other Due to Field Size Distributions
- Spectral Appearance of Soy, Corn, and Other Among Smaller Blobs is Less Unique Causing Mixed Clusters to Form
- As Additional Blobs are Omitted from the Training Set, Corn will Tend to Dominate the Training Set Causing a Bias in its Favor

ILLUSTRATION OF HYPOTHESIS

Definition of Little Blobs

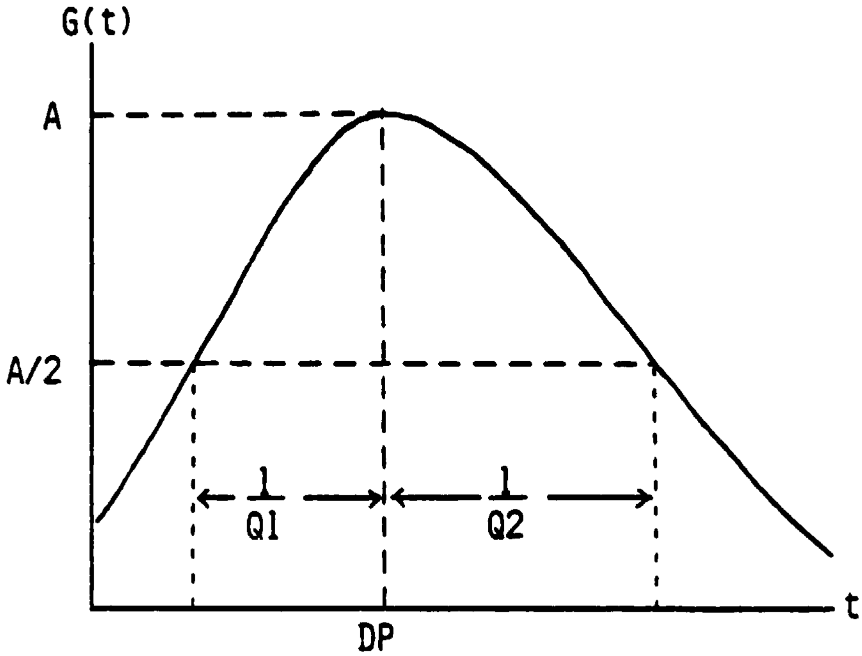
<1 Pixel	<2 Pixels	<3 Pixels



TRUE	Estimate	Estimate	Estimate
C 2/7	1/3	1/2	3/4
S 5/14	1/3	1/3	1/4
O 5/14	1/3	1/6	0

PROFILE DERIVED FEATURES
MODEL FORM USED

- Two-piece Sigmoidal Model
- Used to Fit Tasseled-Cap Variable Greenness as a Function of Time



$$G(t) = \begin{cases} \dfrac{A}{1 + Q1^2(t - DP)^2}, & t < DP \\[2ex] \dfrac{A}{1 + Q2^2(t - DP)^2}, & t \geq DP \end{cases}$$

Interpretation of Parameters:

DP = day of peak Greenness

A = peak Greenness value; i.e., G(t = DP)

Q1 = emergence to peak "Green-up" rate parameter

Q2 = peak to harvest "Green-down" rate parameter

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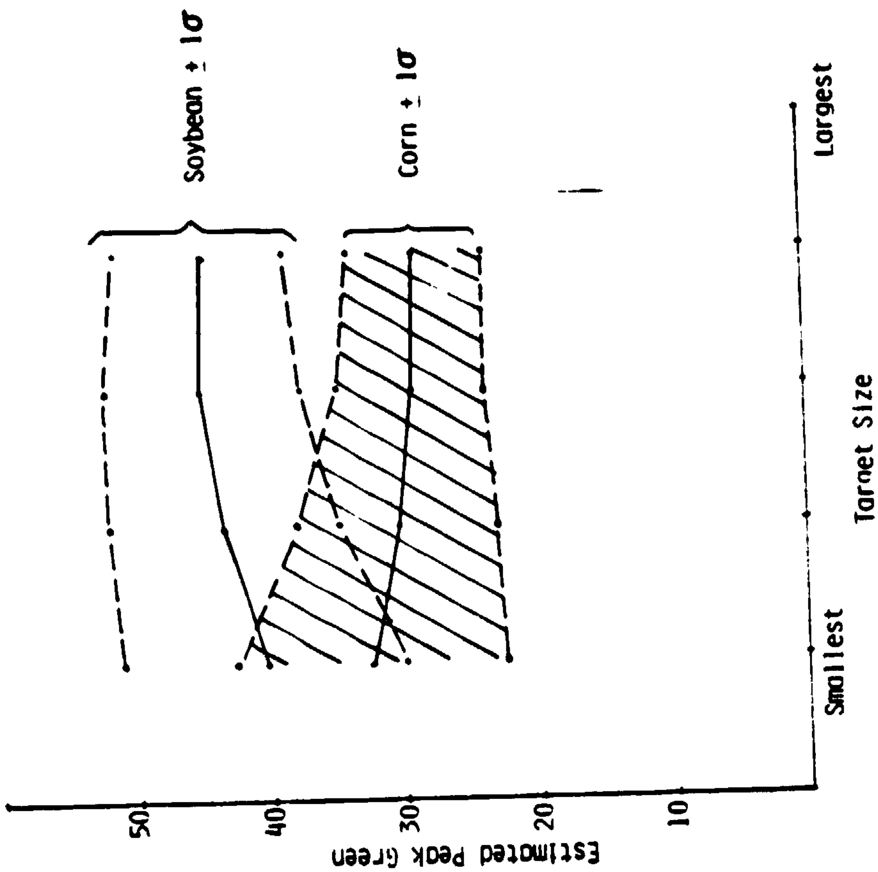
CROP SEPARABILITY AS A FUNCTION OF TARGET SIZE

(9 TY 78 Segments)



TECHNICAL ISSUES

- How is Crop Discrimination Affected Parametrically as a Function of Field Size, Misregistration and Sensor IFOV
- Do Estimation Techniques Exist That are Robust in the Presence of These Conditions

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SMALL FIELDS RESEARCH

H. Horwitz

F. Pont

Environmental Research Institute of Michigan

7 July 1981

OBJECTIVES OF SMALL FIELDS RESEARCH

- Short Range
  - Gain understanding of small fields phenomena
    - •• Interaction between ground and sensor space geometries
    - •• Impact of small fields on crop signatures
    - •• Impact of field size on existing technologies (Blob, CLASSY, etc.)
- Longer Range
  - Support the development of small fields procedures

APPROACH

- Define Small Field as a Field Which Contains No Pure Pixels
- Use a Series of Fixed Field Patterns and Vary Pixel Size (As Pixel Size Increases, Number of Small Fields Increases)
- Uses Several Field Patterns
  - Simulated
  - Landsat
  - Ground truth polygons
- Uses Crop Profiles Obtained from Real Data
- Uses Several Point Spread Functions

MODEL

(x,y)	ground coordinate
(x',y')	misregistration
k	field containing $(x + x', y + y')$
c	crop growing in field k
t	day of year
$P_c(t)$	profile for crop c (Brightness- Greenness)

$$g(x,y) = U_k P_c(t - T_k) + \epsilon_{xy}$$

ground response function

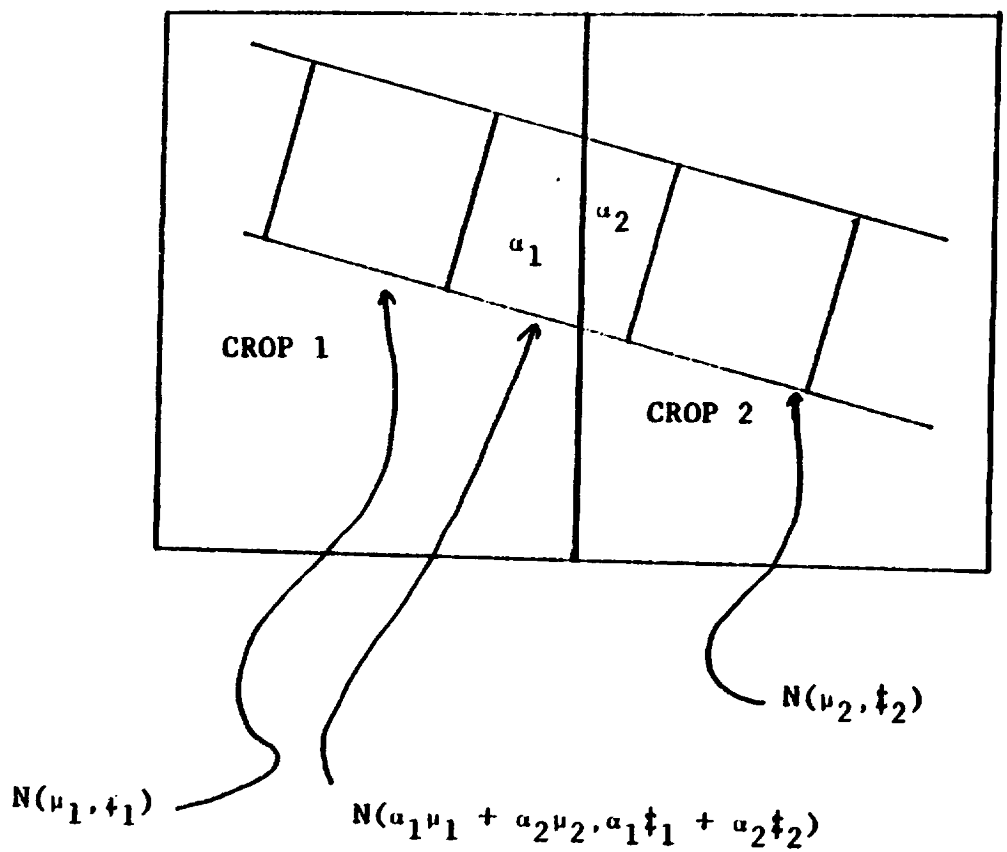
U_k	uniform $(.9,1.1)$ random variable
ϵ_{xy}	noise
T_k	normal (0,100) random variable
ρ	point spread function

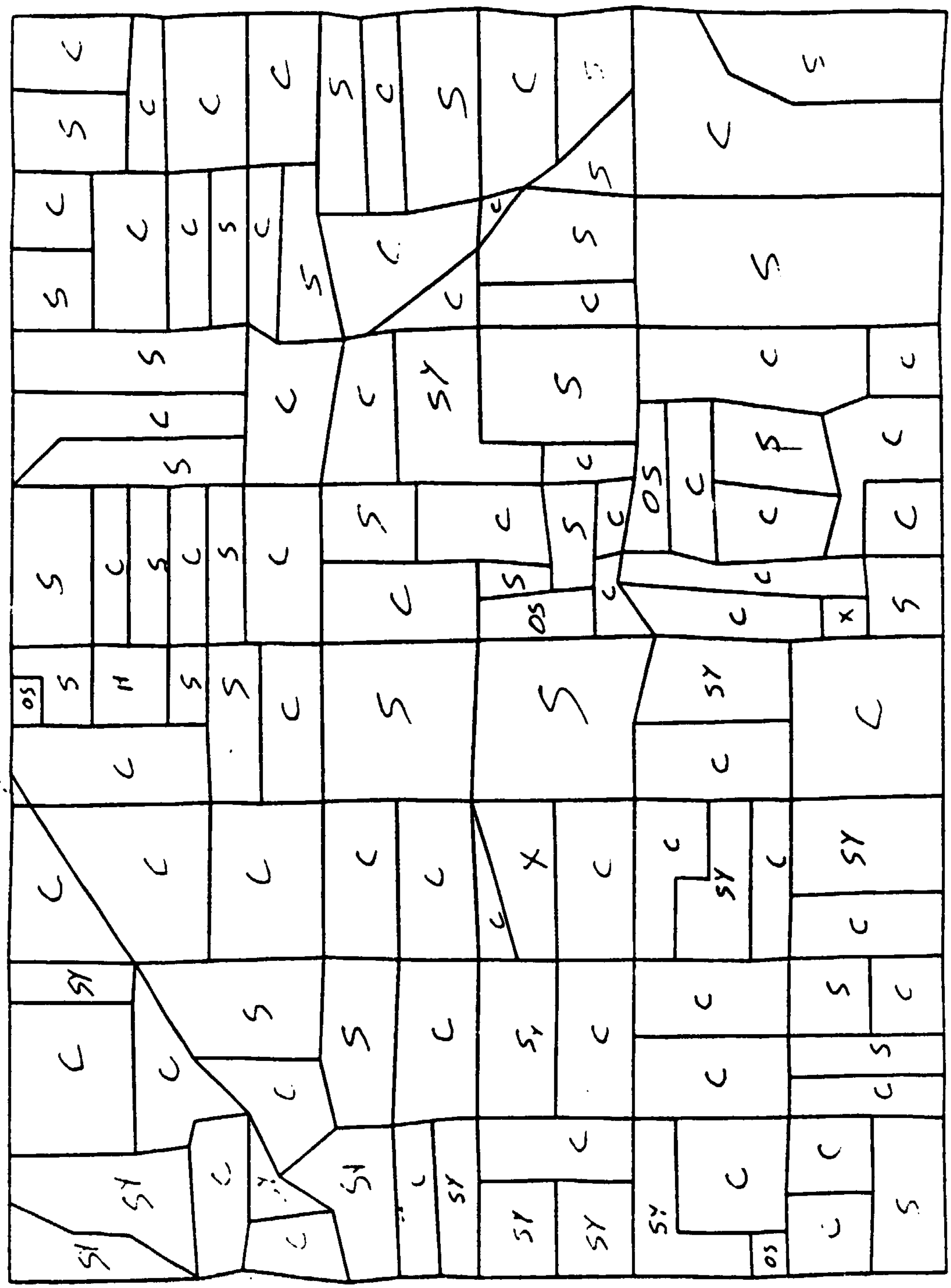
$$f(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(x + x' - r, y + y' - s)\rho(r,s)\,dr\,ds$$

is sensor response

$$\left\{f(x_0 + i\Delta x, y_0 + j\Delta y)\right\}_{i=1,N_x}$$ is sampled sensor response

HORWITZ MODEL FOR FIXED PIXEL





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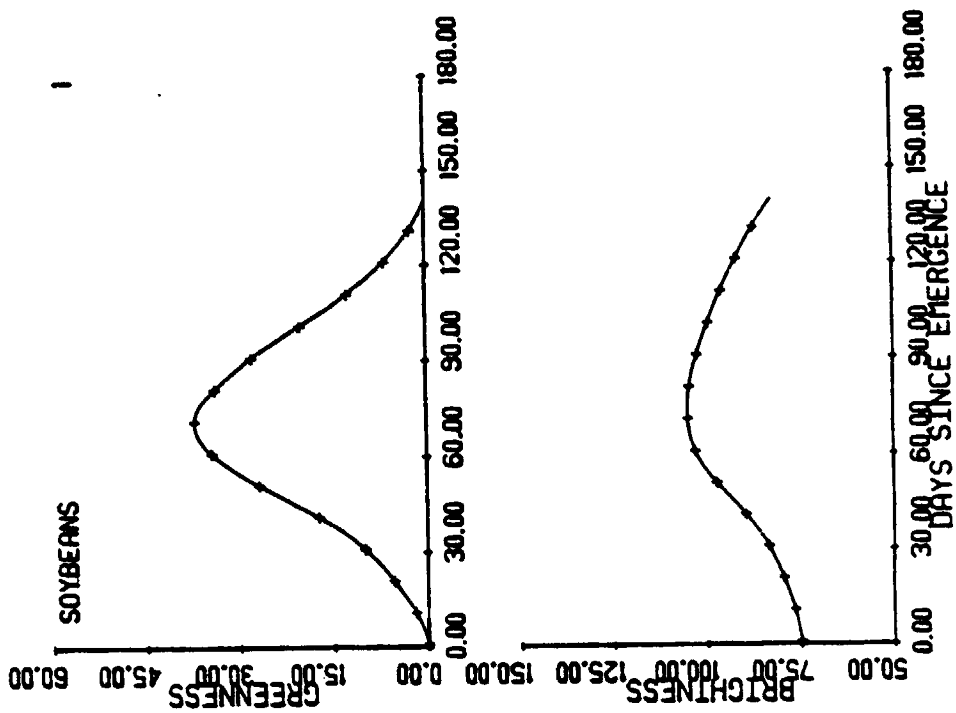

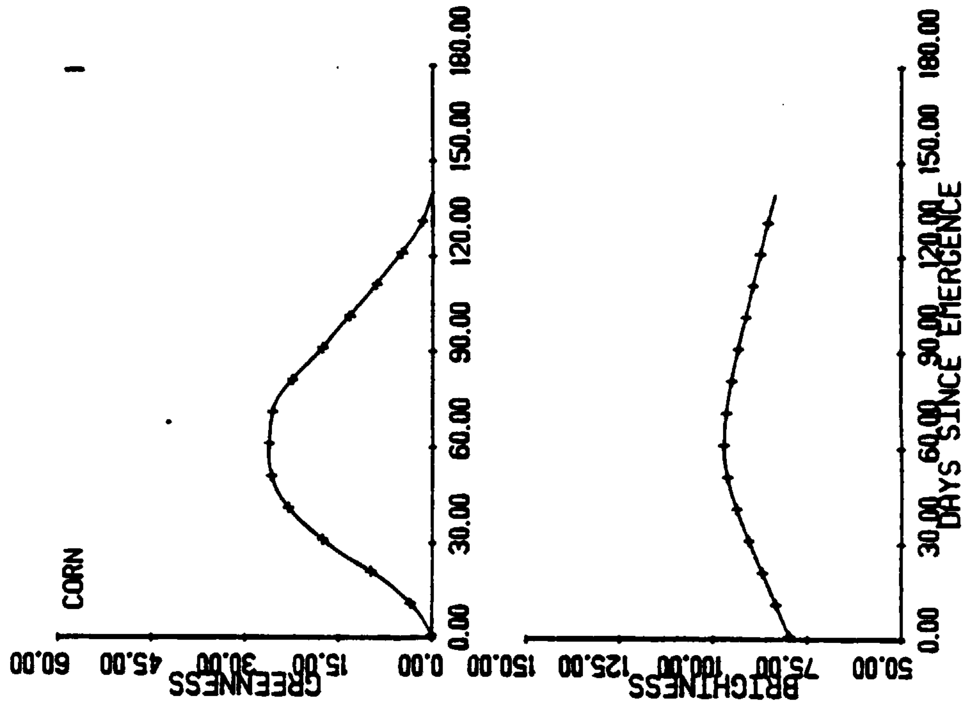
CORN
GREENNESS
0.00
15.00
30.00
45.00
60.00
BRIGHTNESS
50.00
75.00
100.00
125.00
150.00
DAYS SINCE EMERGENCE
0.00
30.00
60.00
90.00
120.00
150.00
180.00

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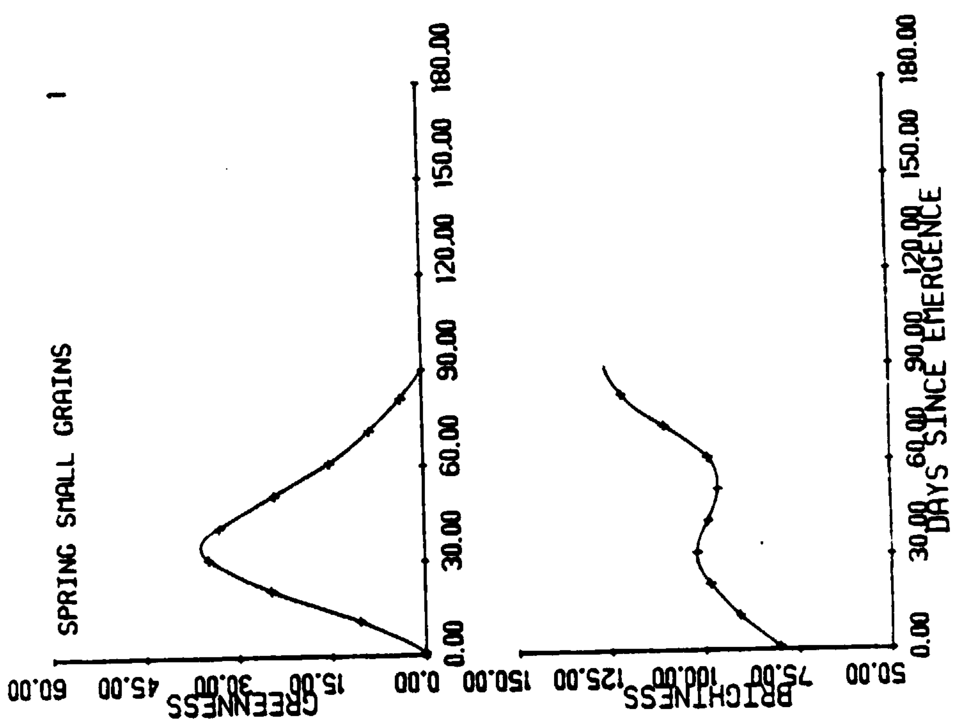
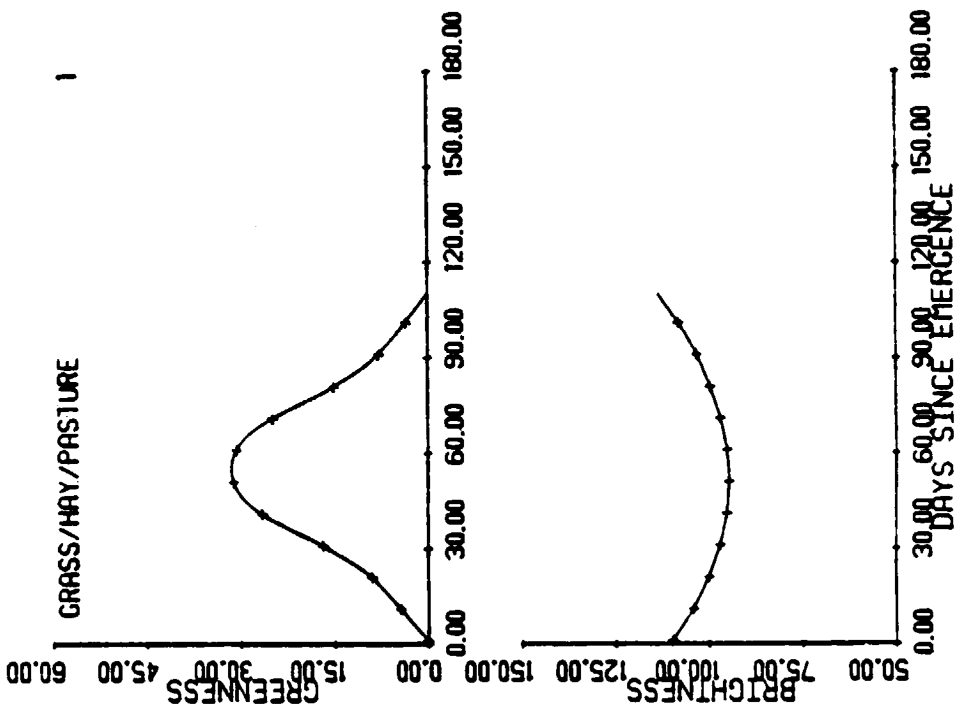
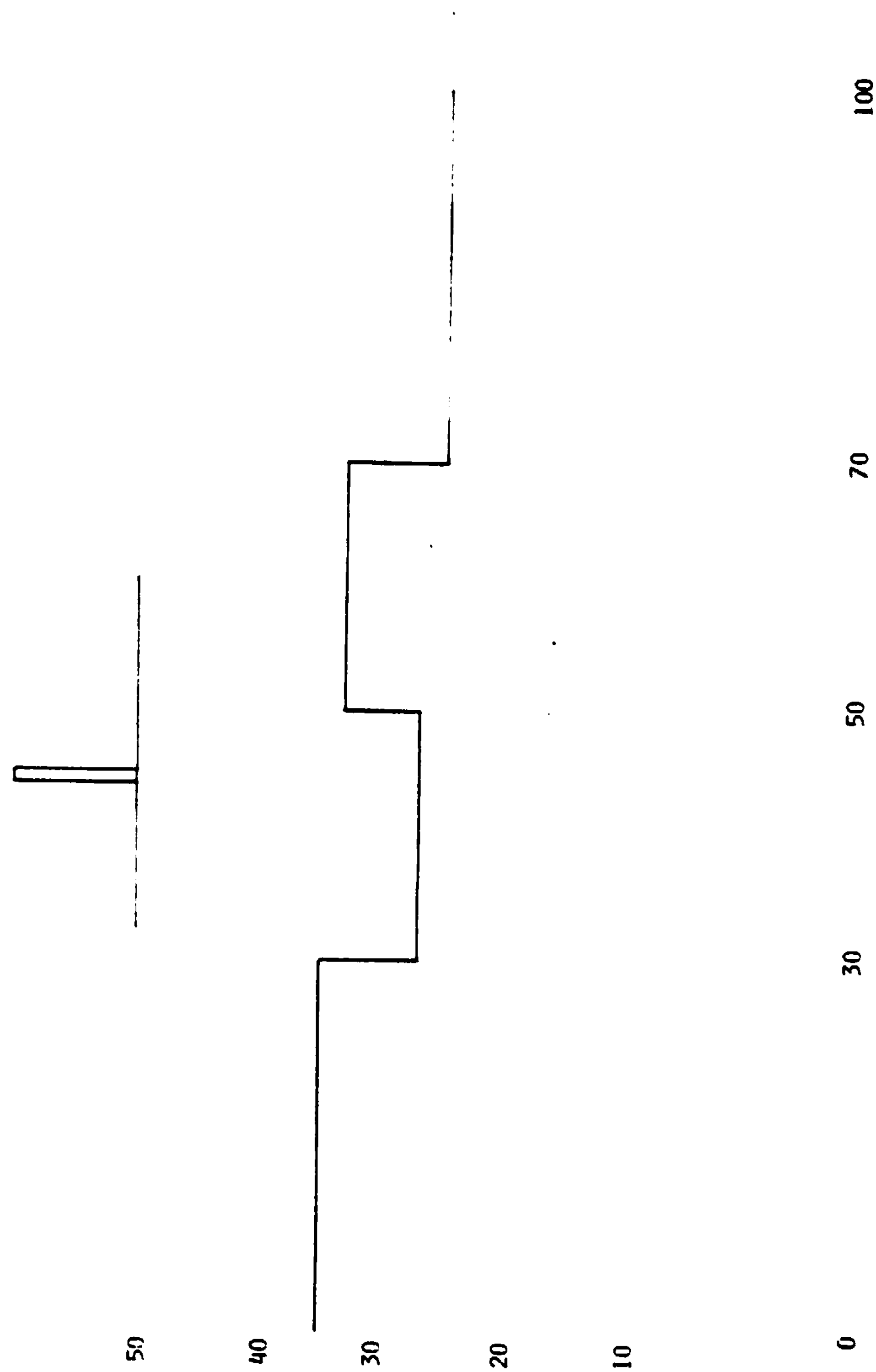
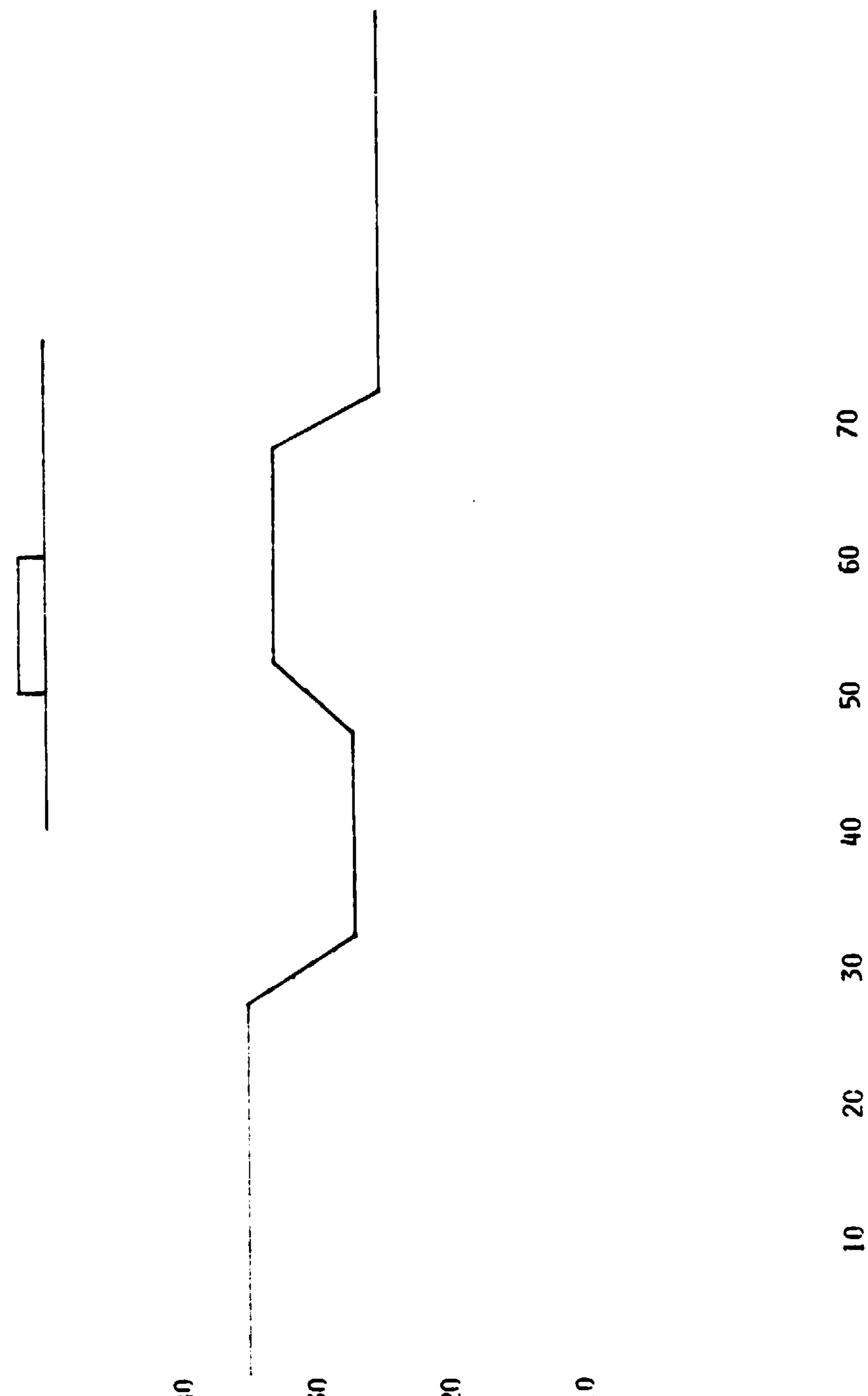



GRASS/HAY/PASTURE
GREENNESS
0.00
15.00
30.00
45.00
60.00
BRIGHTNESS
50.00
75.00
100.00
125.00
150.00
DAYS SINCE EMERGENCE
0.00
30.00
60.00
90.00
120.00
150.00
180.00


100
70
50
30
0
50
40
30
20
10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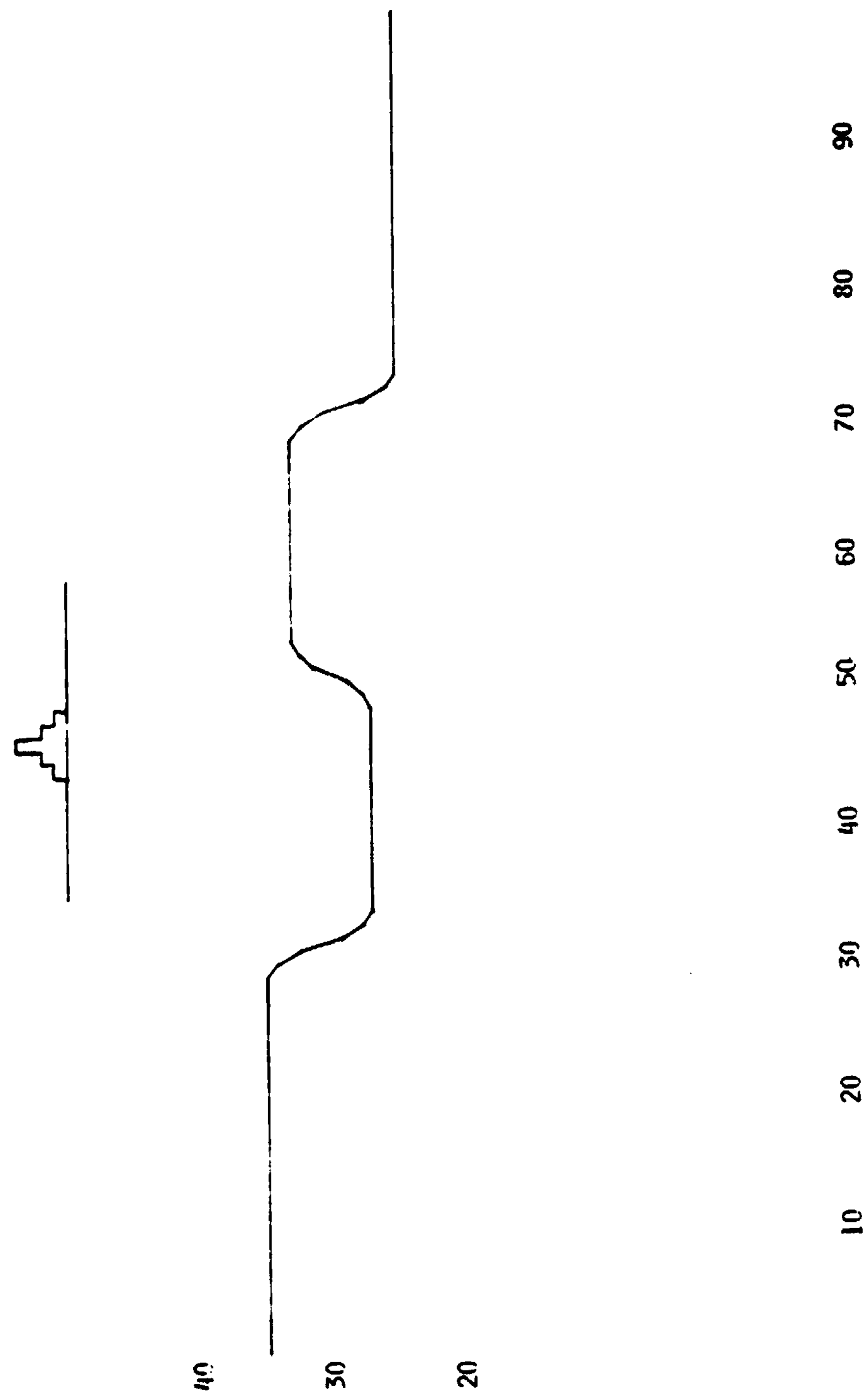
20
10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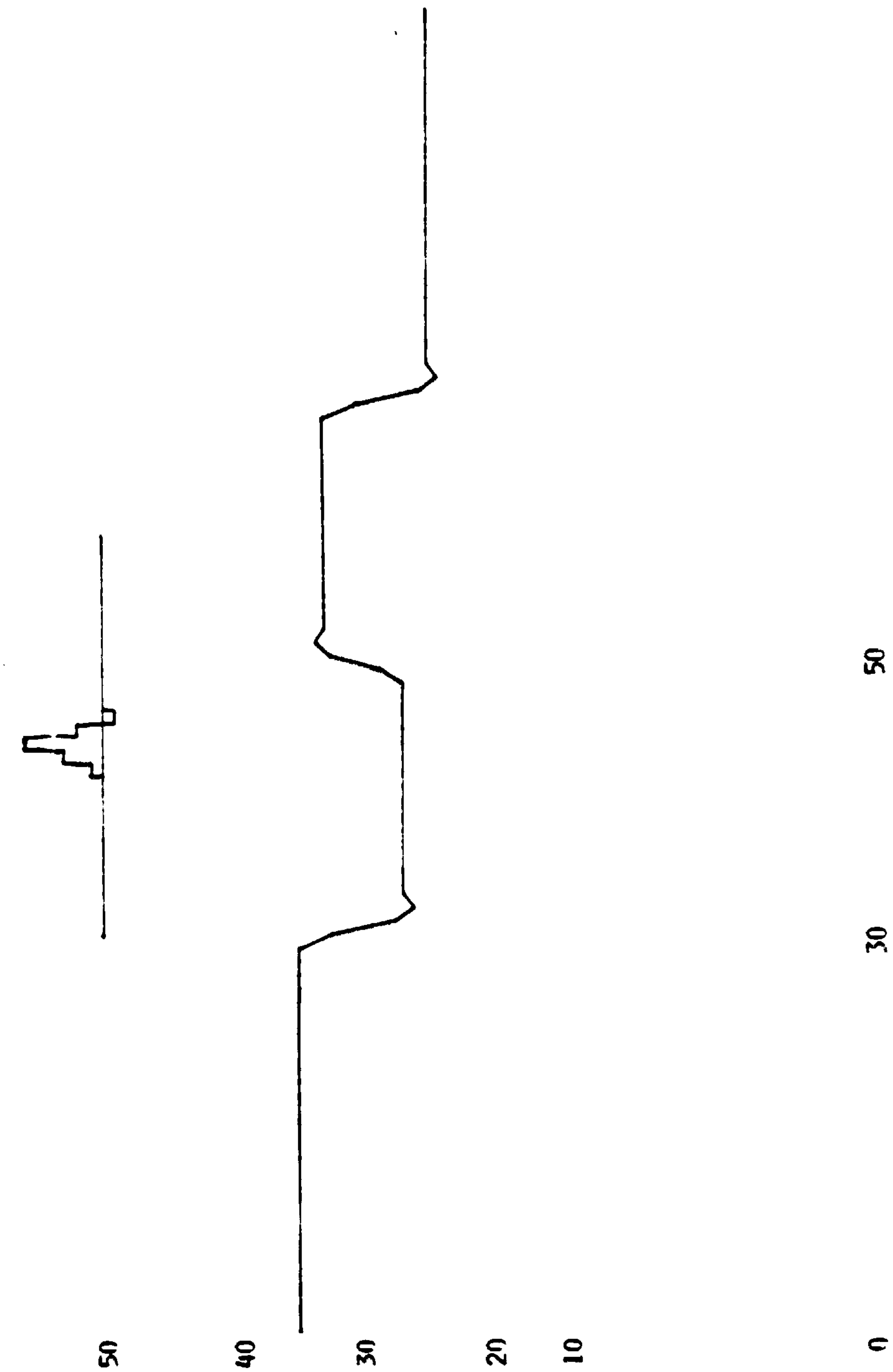
50
40
30
20
10
0
30
50

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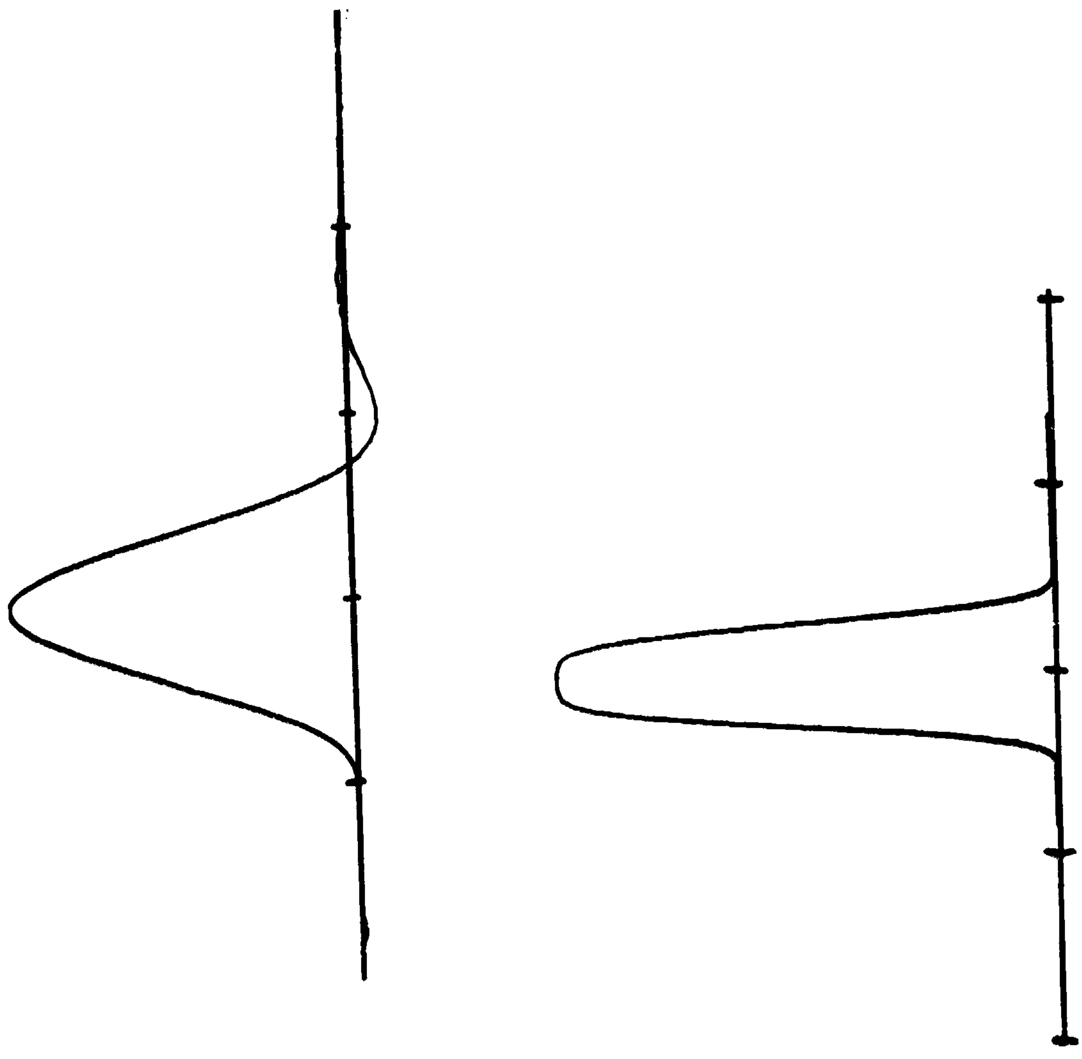

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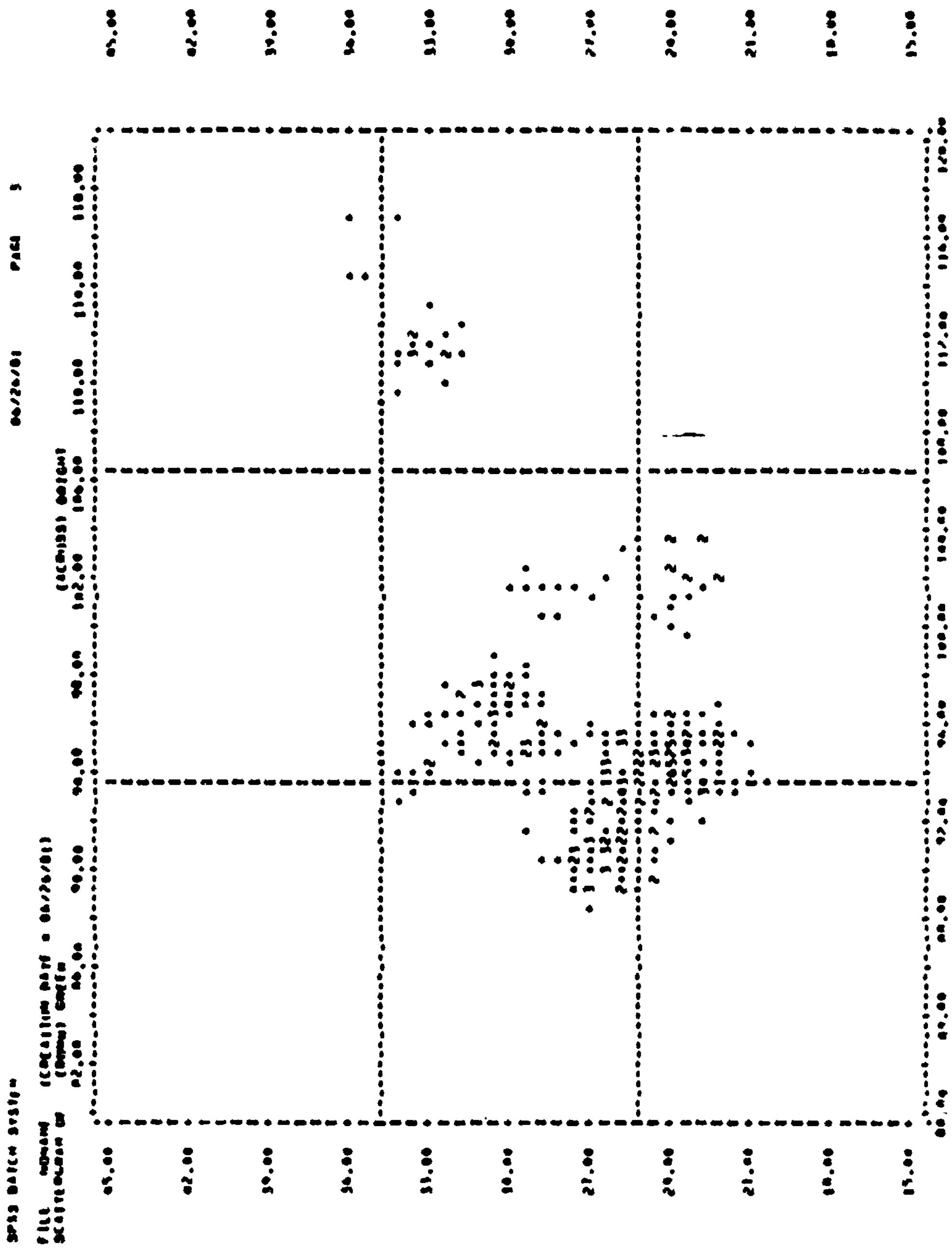

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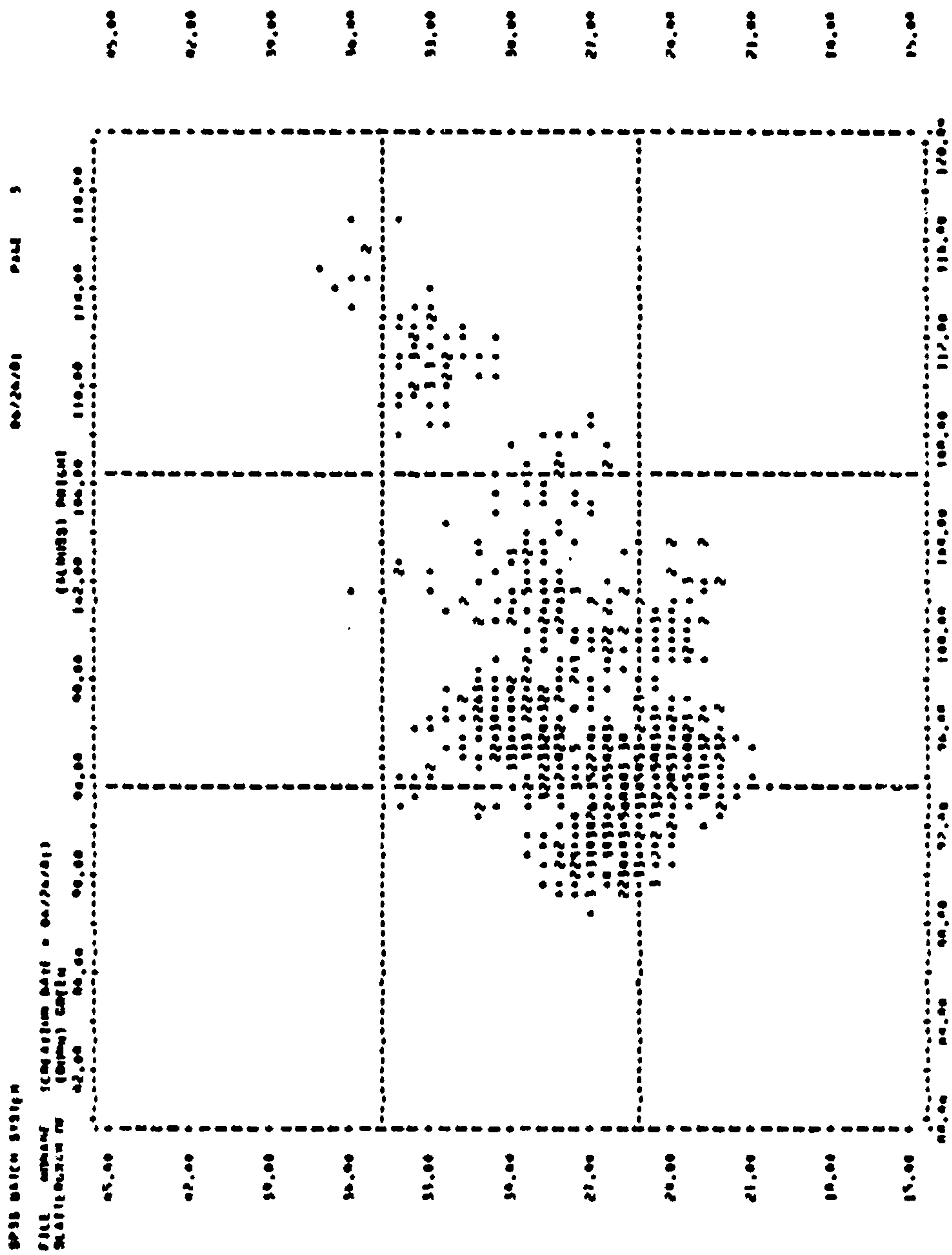

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Crist, E. P. and Malila, W. A. Development and Evaluation of an Automatic Labeling Technique for Spring Small Grains. Report Number (ERIM) 152400-3-T, June 1981.

Dye, R. H. Restoration of Landsat Images by Discrete Two Dimensional Deconvolution. Proceedings of the Tenth International Symposium on Remote Sensing of Environment, October 1975.

Nalepka, R. F., Horwitz, H. M., and Hyde, P. D. Estimating Proportions of Objects from Multispectral Data. Report Number (WRL) 31650-73-T, March 1972.

SIMULATING THE SPECTRAL APPEARANCE OF WHEAT AS A FUNCTION OF ITS GROWTH AND DEVELOPMENT

Presented At: AgRISTARS Supporting Research Quarterly Technical Interchange Meeting

Performing Organization: Environmental Research Institute of Michigan
Ann Arbor, MI

Contributors: G. Suits, R. Sieron, W. Malila

Presented By: W. A. Malila

Date: 8 July 1981

OUTLINE

- Introduction
  - Problems Addressed
  - Objective
  - Overview of Seed-to-Satellite Model Concept
- Model Development for Wheat
  - Ritchie Growth Model
  - Interfacing to Suits Canopy Reflectance Model
  - Parameters That Can Be Varied
- Initial Results: Parametric Studies
- Summary
  - Needs from Supporting Field Research
  - Plans

PROBLEMS ADDRESSED

- Effects of Crop Physiological Parameters, the Driving Meteorological Variables, and Atmospheric and Sensor Characteristics on Spectral Observations are Not Well Enough Understood

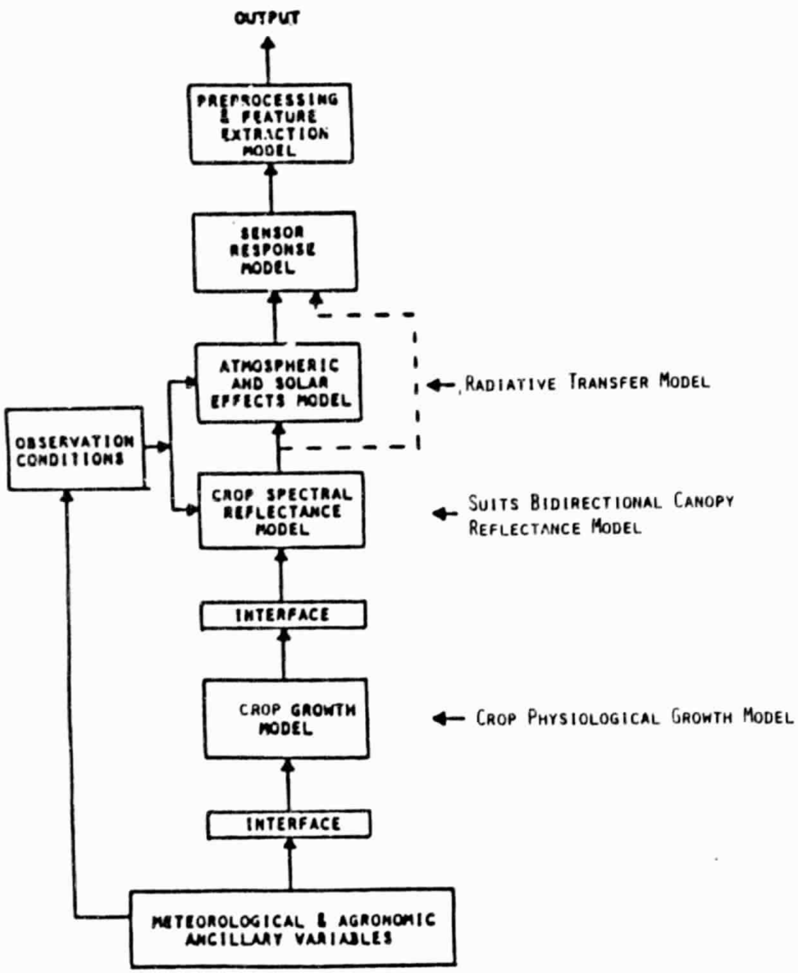
- Field Measurements are not Practical Under All the Relevant Observation Conditions and Situations

- Simulation Models Have Many Pertinent Uses in AgRISTARS Research but Current Models Do Not Adequately Represents the Full Range and Character of Factors That Affect Remotely Sensed Data

OBJECTIVE

- To Develop a Simulation Capability That Will Help Researchers Better Understand the Effects of Those Factors Which Affect the Observable Spectral Characteristics of Crops

"SEED-TO-SATELLITE" MODEL

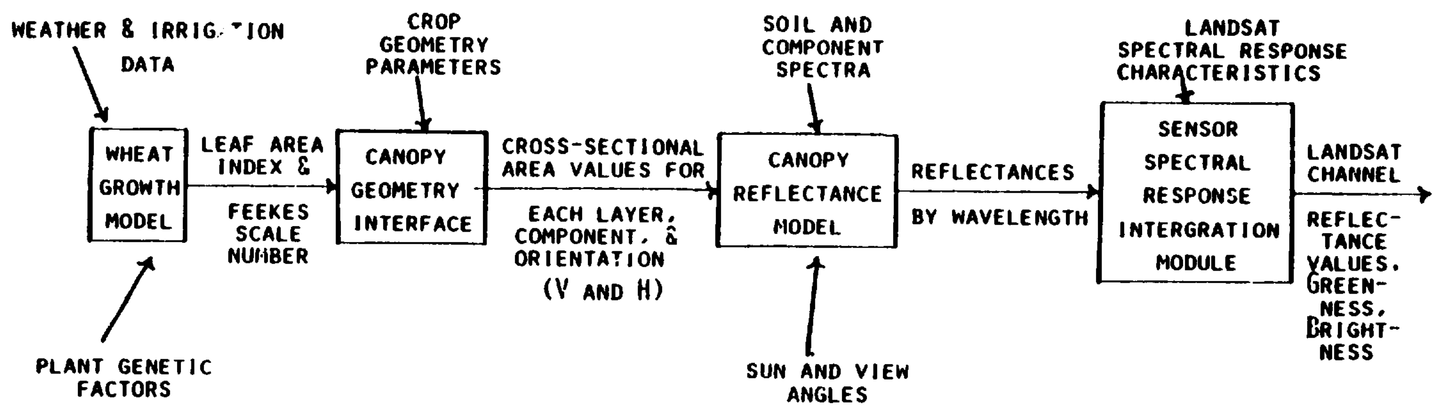


PLANNED ORDER FOR ADDRESSING CROPS

- Wheat
- Barley
- Soybeans
- Corn
- Selected Confusion Crops

INFORMATION FLOW THROUGH THE

WHEAT REFLECTANCE SIMULATOR



RITCHIE WHEAT MODEL

- Under Development by a Team of Researchers at USDA/SEA, Temple, TX

- An Ecological-Level Model That Uses Rational Empiricisms to Estimate Main Features of Several Complicated and Detailed Processes

- Main Components
    - Soil water balance
    - Phasic development (using thermal development units)
    - Vegetative development
    - Biomass accumulation
    - Yield

- Development Versions (two of several)
    - November '79 version -- used for the work reported herein
-- has some known weaknesses
    - Improved version -- applies to barley as well as wheat
-- to be obtained and integrated next

INTERFACE BETWEEN RITCHIE WHEAT MODEL AND SUITS REFLECTANCE MODEL

Wheat Model Outputs	Reflectance Model Inputs
LAI	Spectral Classes Present in Each Layer
Stage of Development	Vertical and Horizontal Cross-Sections for Each Spectral Class (by layer)
Number of Stems and Heads	Spectral Reflectance and Transmittance for Each Spectral Class
	Sun and View Angles

Interface Functions

Specify Crop Structure and Geometry vs. Stage of Development

Partition Into Spectral Classes

FACTORS AFFECTING REFLECTANCE OF CROPS

- DIRECT:

Factor	Physical Properties
Plant Components:	- Amount of each (e.g., LAI) - Orientation of each (V, H) - Spectral Characteristics of each ($\rho(\lambda)$, $\tau(\lambda)$)
Canopy:	- Overall Structure (e.g., rows) - Uniformity
Soil Background:	- Spectral Reflectance - Surface Texture, Pattern and Slope
Illumination:	- Sun's Angular Position - Fraction of diffuse skylight
Viewer:	- Angular Direction

FACTORS AFFECTING REFLECTANCE OF CROPS (Cont'd)

- INDIRECT:

Affecting What is Present and When	Affecting How it Appears
Plant Stage of Development	Level of Stress
Plant Growth and Condition	- Moisture
Agronomic Management Practices	- Disease
- Planting date	- Insect
- Planting density and pattern	- Nutrient
- Fertilization	Time of Day
- Irrigation	- Diurnal changes in structure
- Cultivation	
- Chemical control	Weeds
Soil Characteristics	Wind
Weather History	
- Temperature	
- Precipitation	
- Illumination	

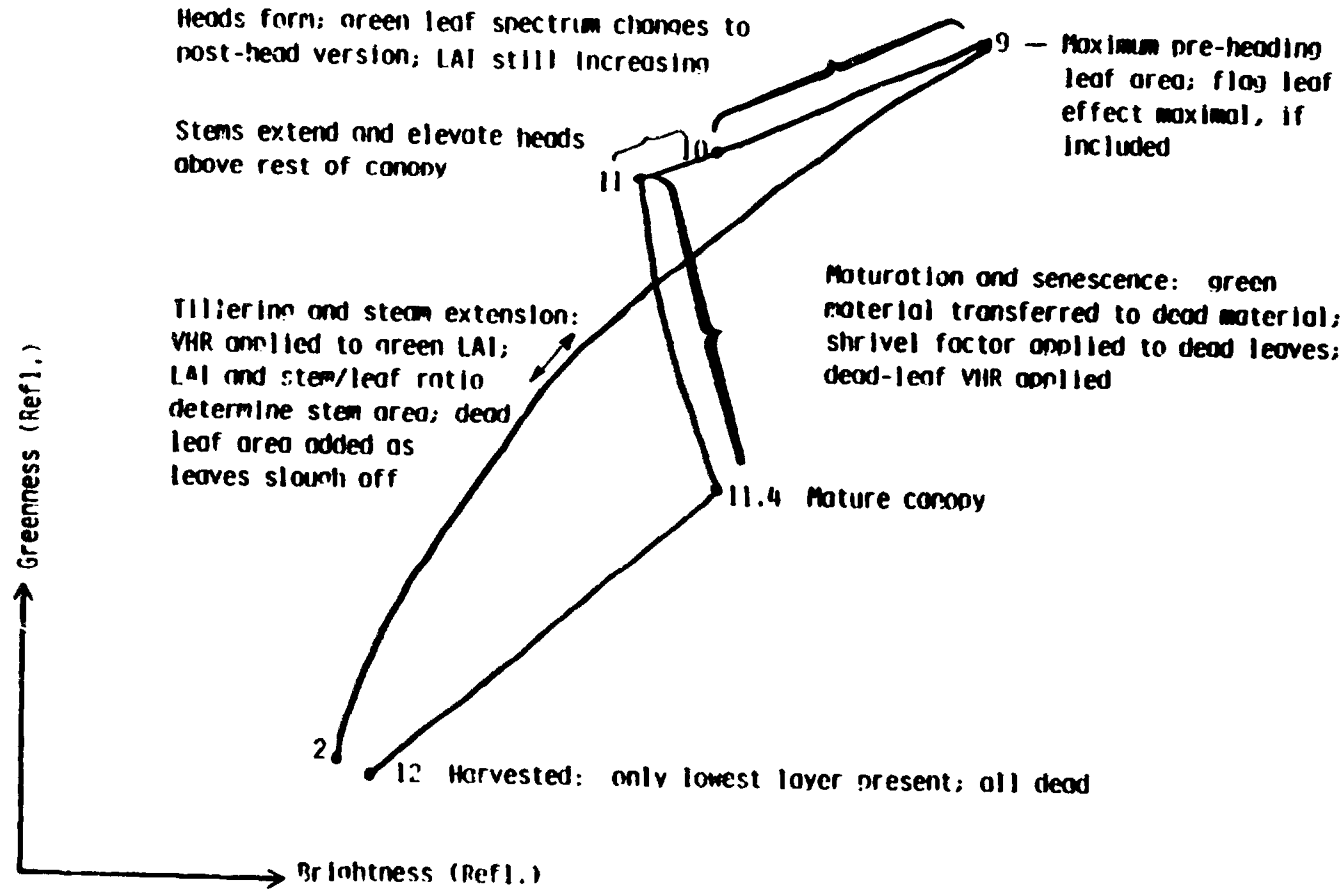
INITIAL RESULTS

- Parameteric Studies Using November '79 Version of Wheat Model
- Weather Data and Plant Genetic Factors for a Test Data Set from Rothamsted, England

PHENOMENA ASSOCIATED WITH WHEAT REFLECTANCE CHANGES

(General Curve Shape in Transformed MSS Bands)

(Numbers Denote Modified Feekes Scale)



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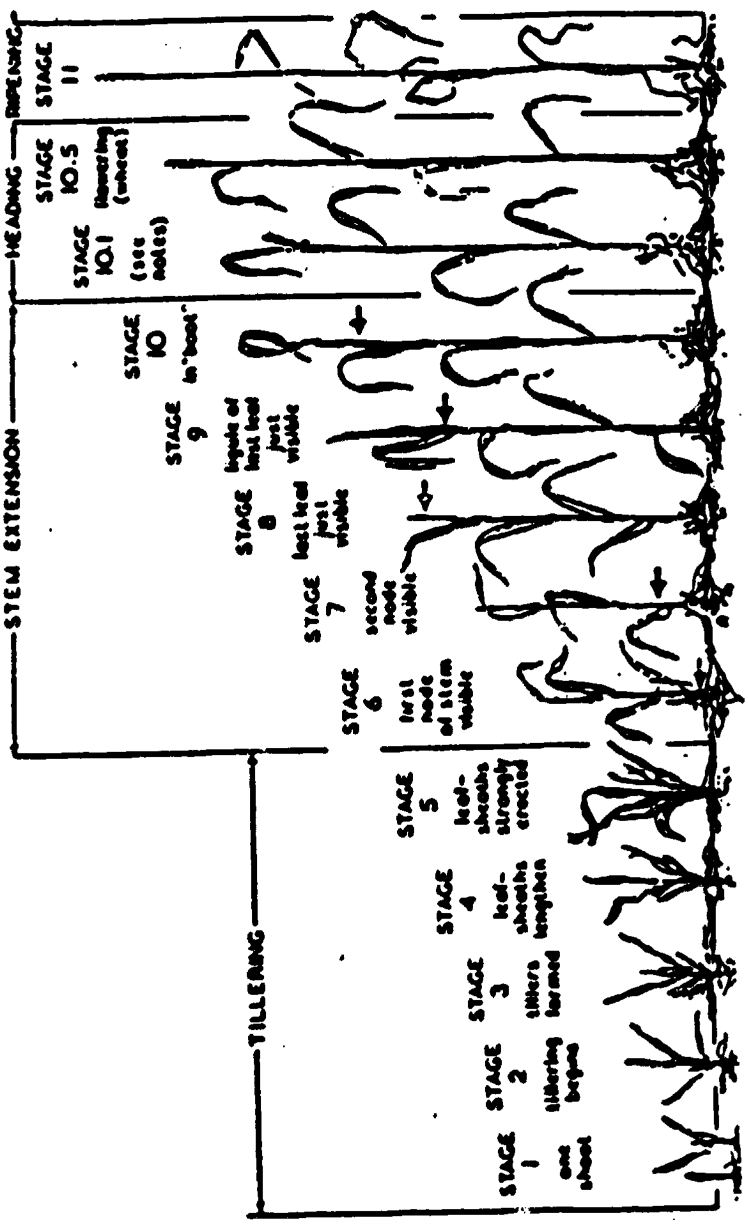
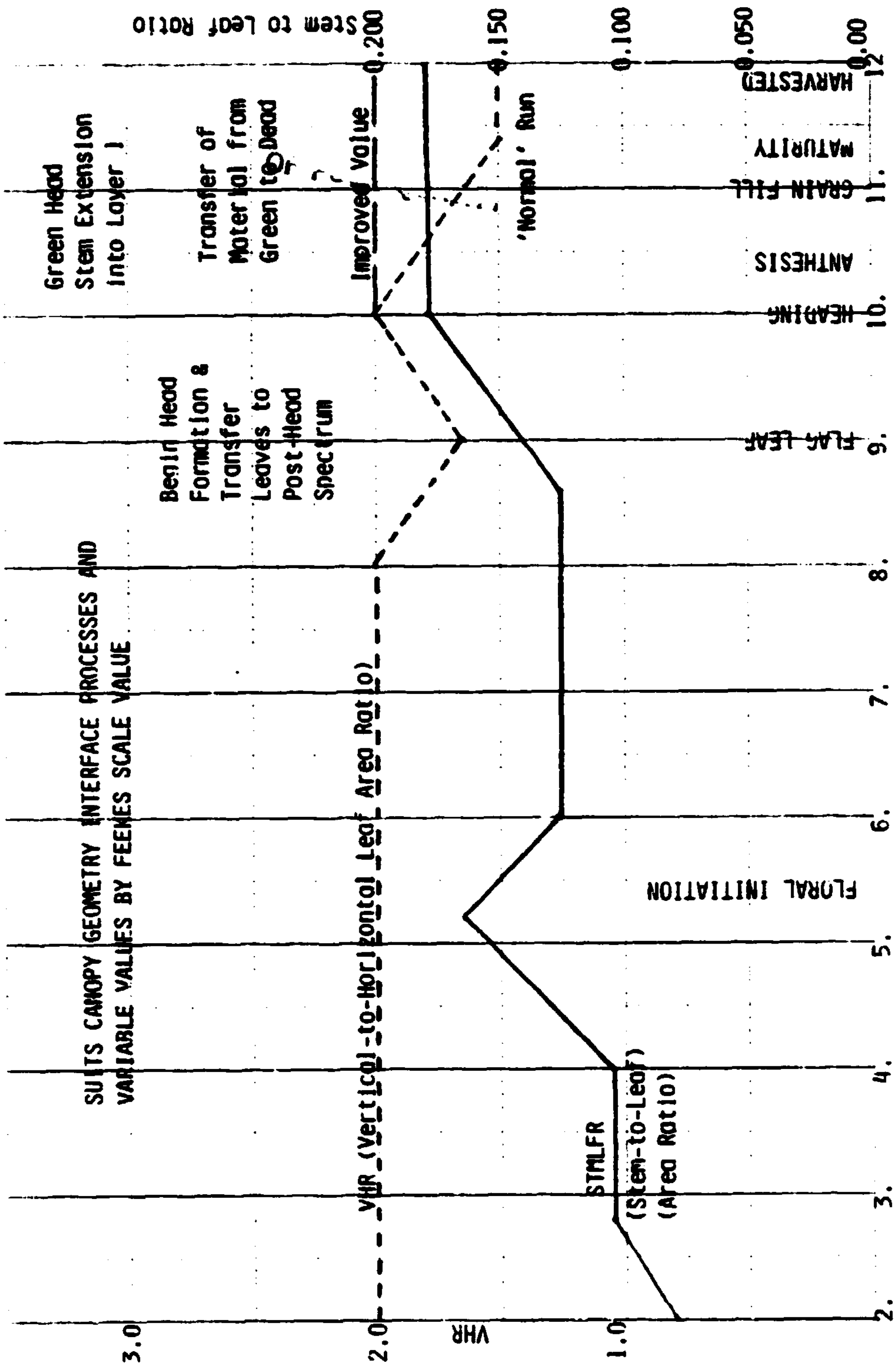


Growth Stages in Cereals
(Modified Feekes Scale)


Stem to Leaf Ratio
0.200
0.150
0.100
0.050
0.00
HARVESTED
MATURITY
GRAIN FILL
ANTHESIS
HEADING
FLAG LEAF
FLORAL INITIATION
Green Head Stem Extension Into Layer 1
Transfer of Material from Green to Dead
Improved Value
'Normal' Run
Begin Head Formation & Transfer Leaves to Post-Head Spectrum
SUITS CANOPY GEOMETRY INTERFACE PROCESSES AND VARIABLE VALUES BY FEEKES SCALE VALUE
VHR (Vertical-to-Horizontal Leaf Area Ratio)
STMLFR (Stem-to-Leaf) (Area Ratio)
VHR
3.0
2.0
1.0
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12

C-2

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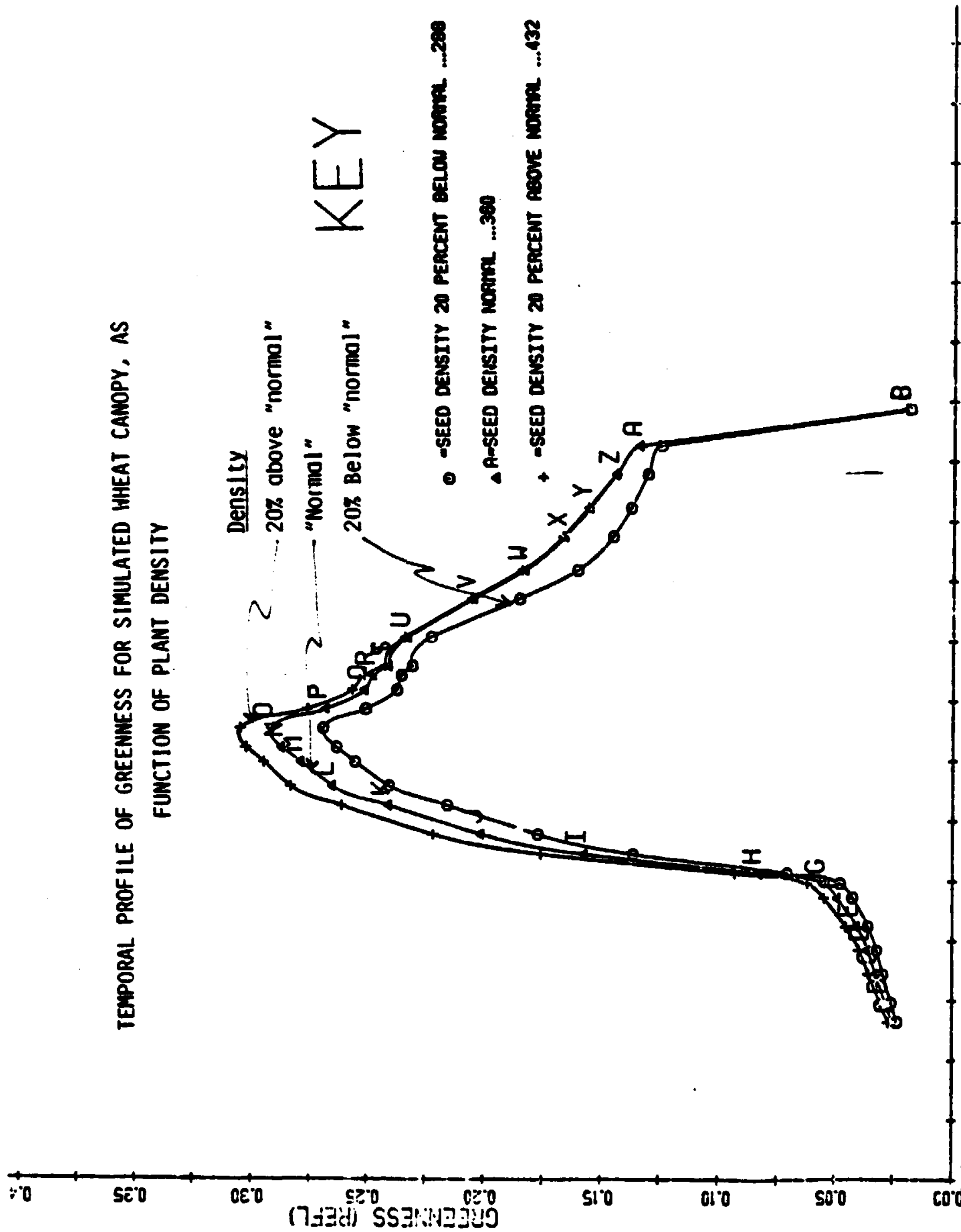

TEMPORAL PROFILE OF GREENNESS FOR SIMULATED WHEAT CANOPY, AS FUNCTION OF PLANT DENSITY

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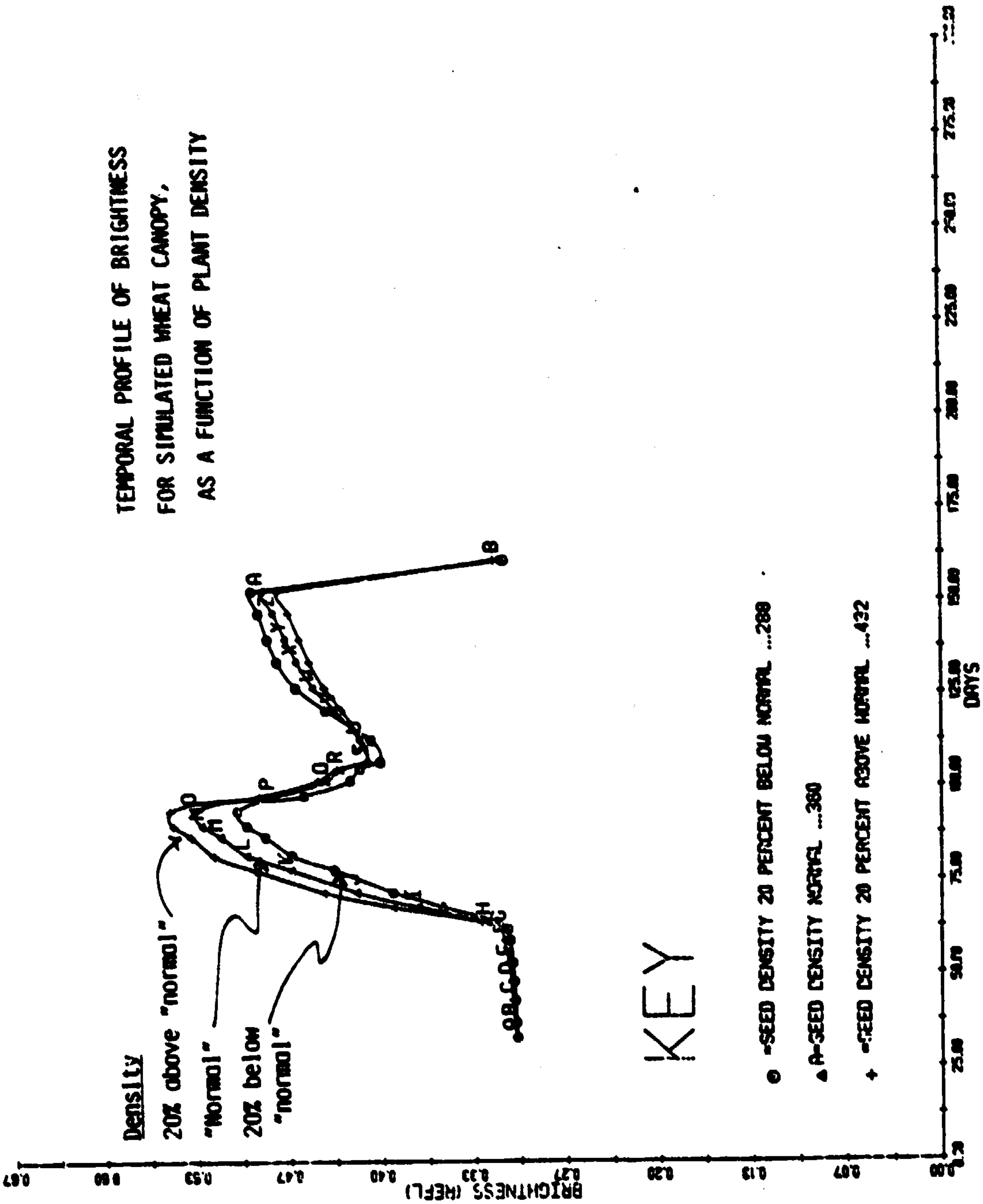

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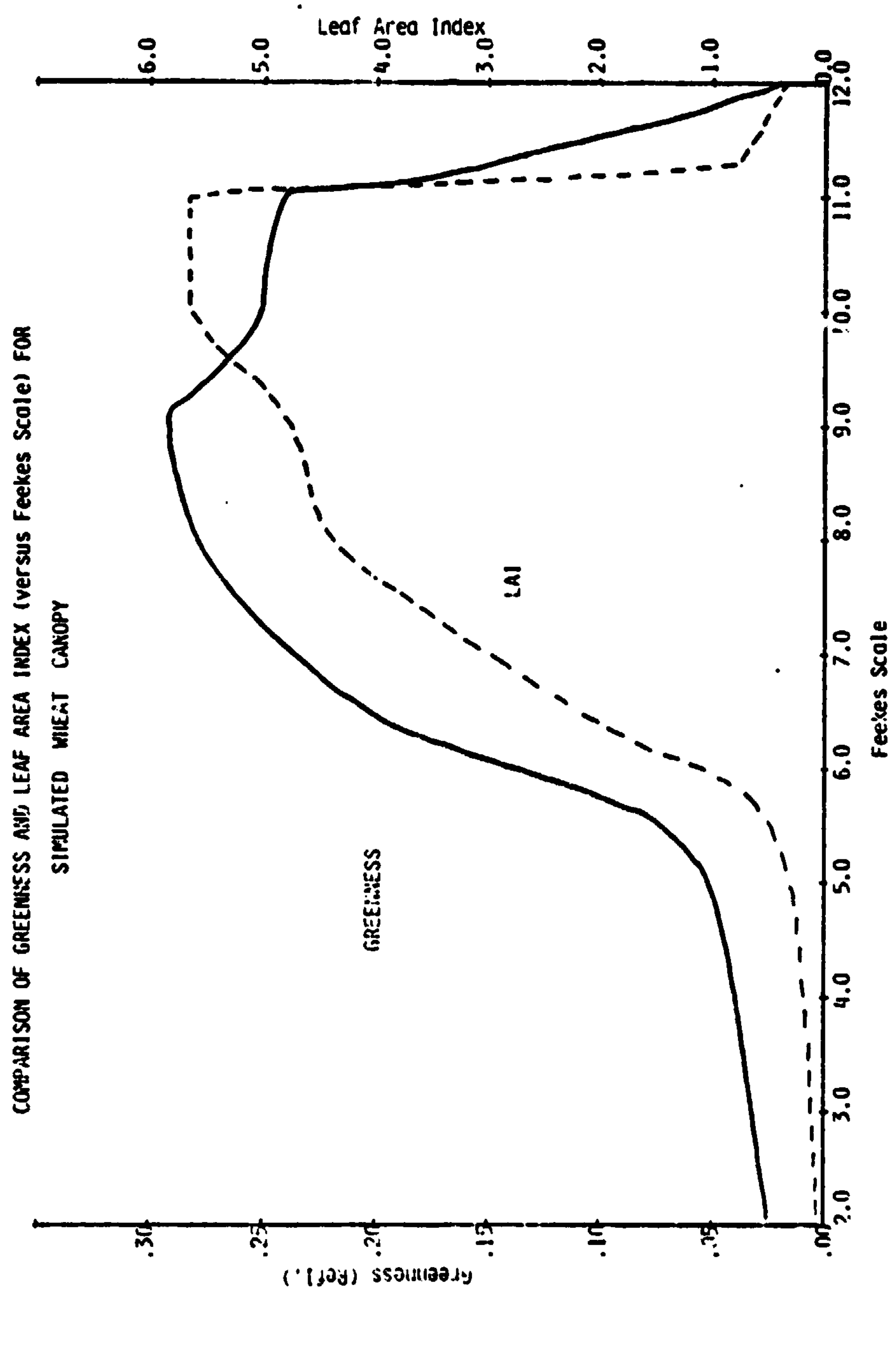

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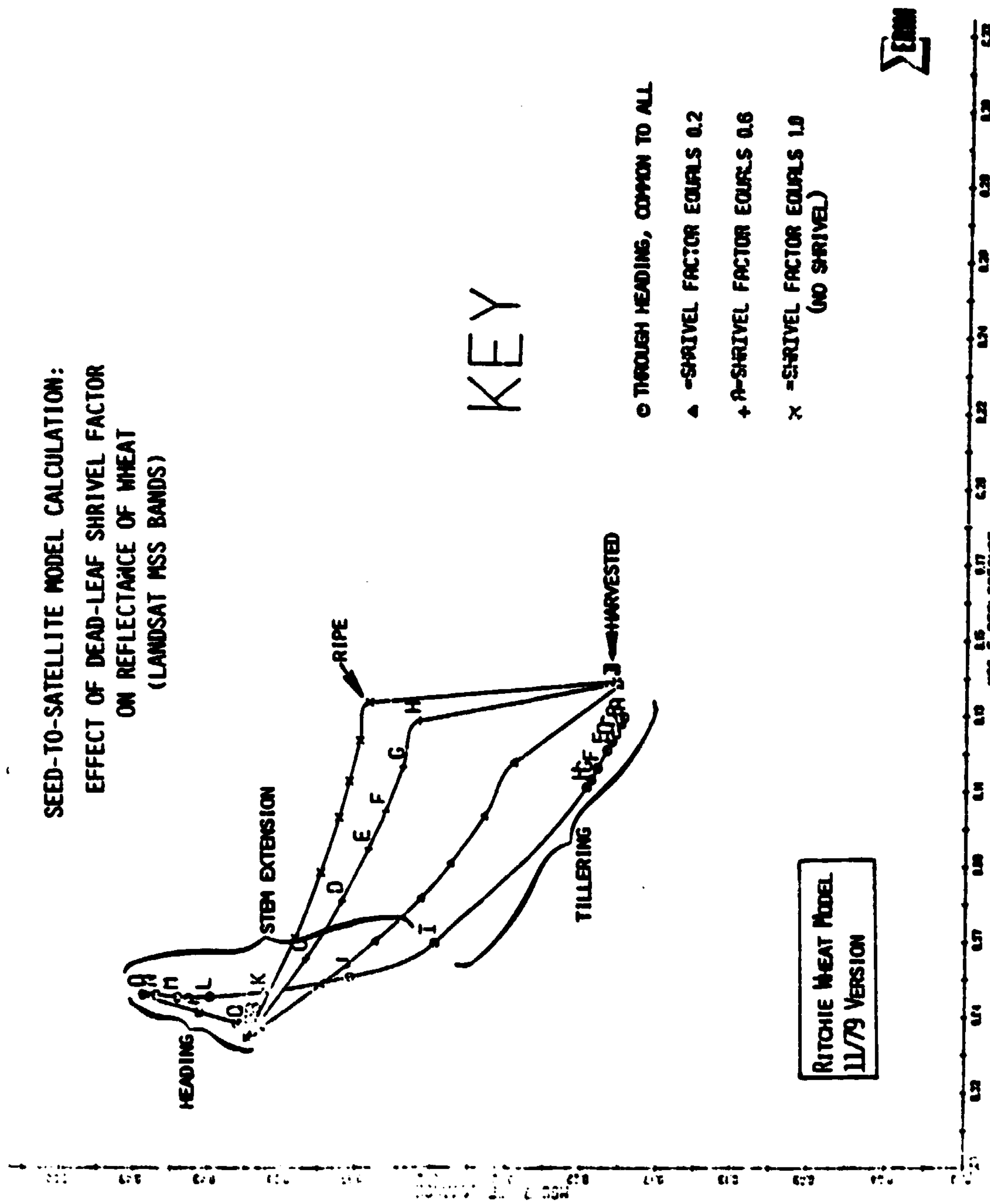

SEED-TO-SATELLITE MODEL CALCULATION:
EFFECT OF DEAD-LEAF SHRIVEL FACTOR
ON REFLECTANCE OF WHEAT
(LANDSAT MSS BANDS)

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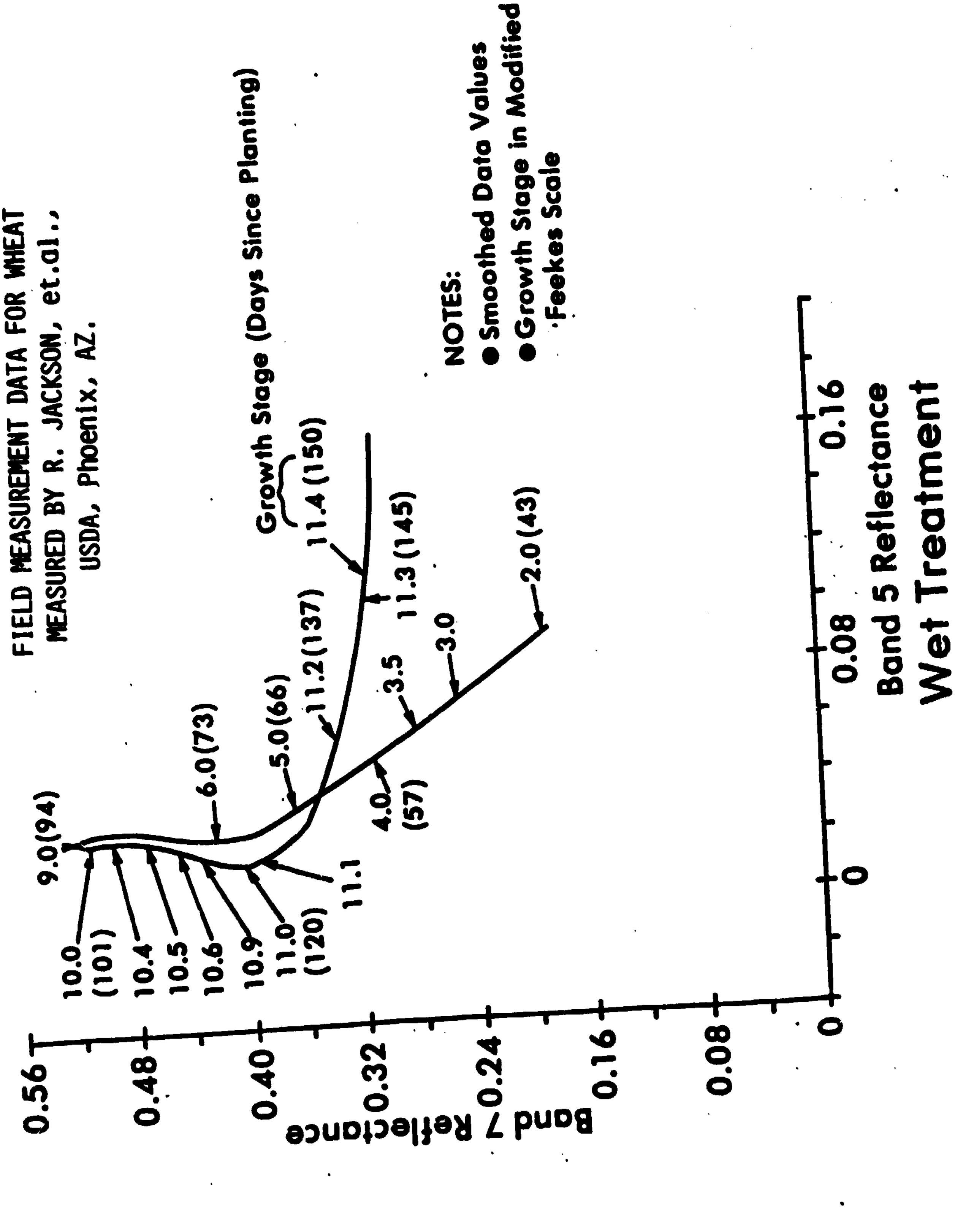
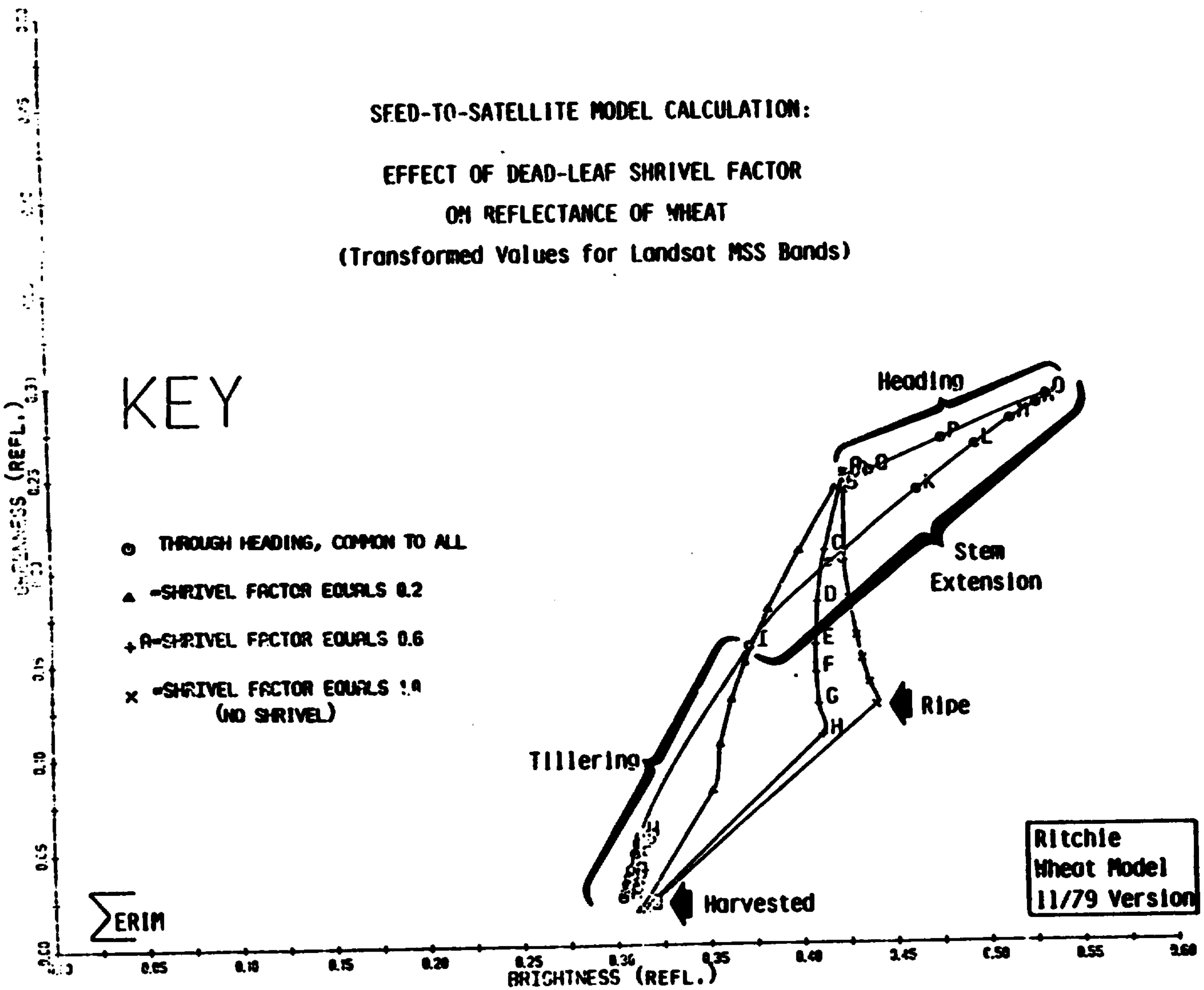


SEED-TO-SATELLITE MODEL CALCULATION:

EFFECT OF DEAD-LEAF SHRIVEL FACTOR
ON REFLECTANCE OF WHEAT
(Transformed Values for Landsat MSS Bands)



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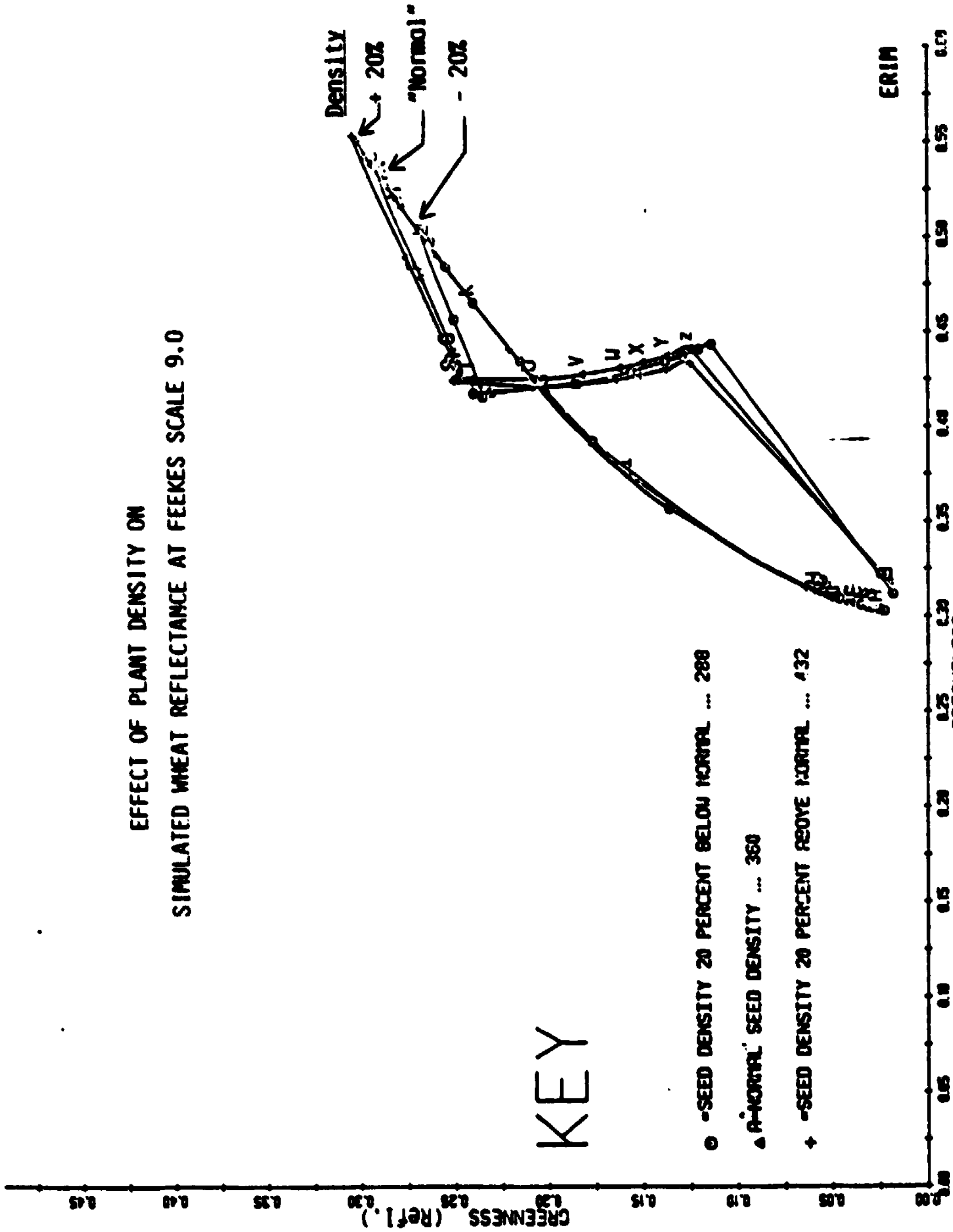
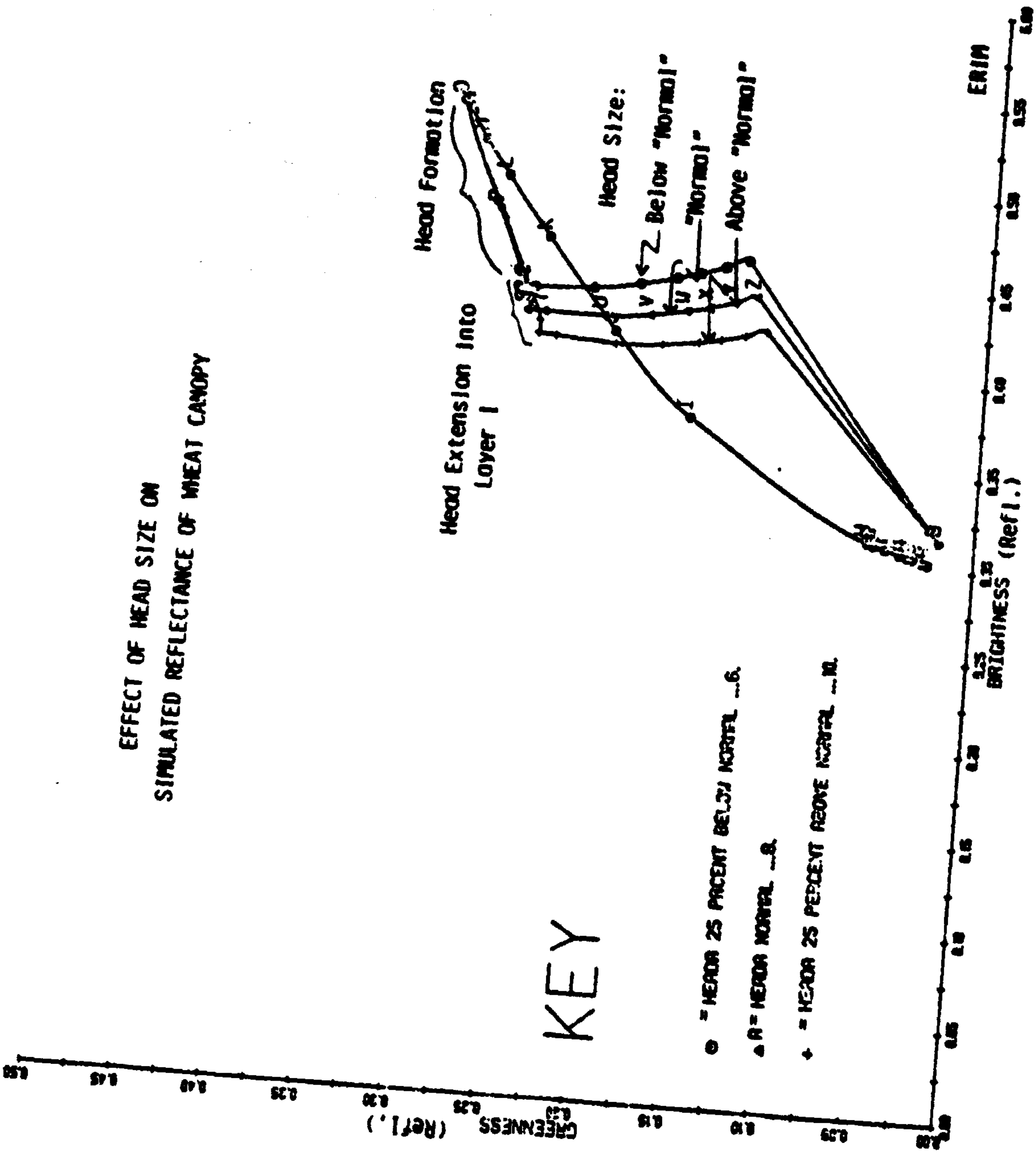
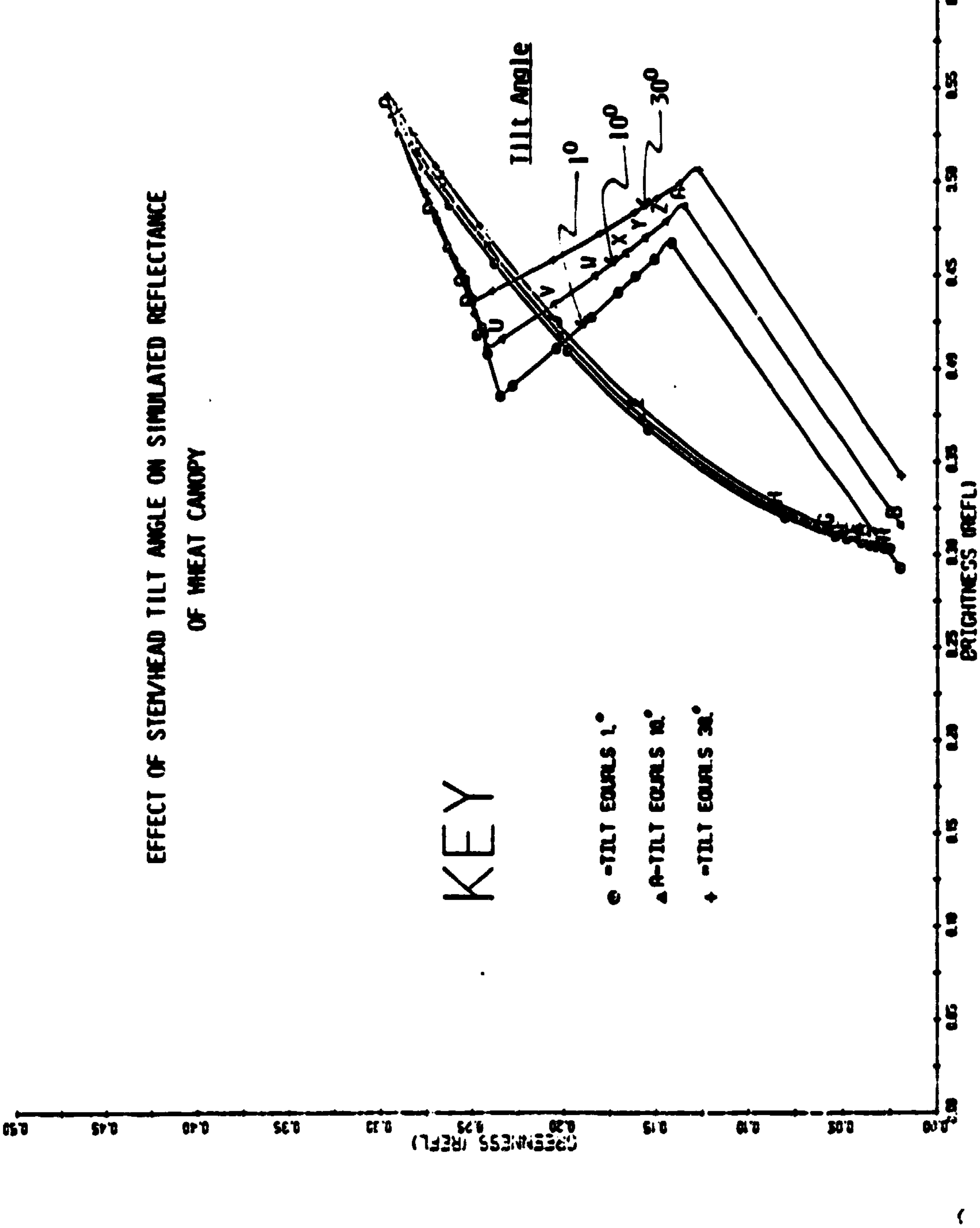



EFFECT OF HEAD SIZE ON
SIMULATED REFLECTANCE OF WHEAT CANOPY
Head Formation
Head Extension Into
Layer I
Head Size:
Below "Normal"
"Normal"
Above "Normal"
ERIM
BRIGHTNESS (Refl.)
GREENNESS (Refl.)
KEY
⊖ = HEADS 25 PERCENT BELOW NORMAL ...6.
△ R = HEADS NORMAL ...8.
+ = HEADS 25 PERCENT ABOVE NORMAL ...10.


EFFECT OF STEM/HEAD TILT ANGLE ON SIMULATED REFLECTANCE
OF WHEAT CANOPY
Tilt Angle
1°
10°
30°
KEY
-TILT EQUALS 1°
A-TILT EQUALS 10°
-TILT EQUALS 30°
BRIGHTNESS (REFL)
GREENNESS (REFL)

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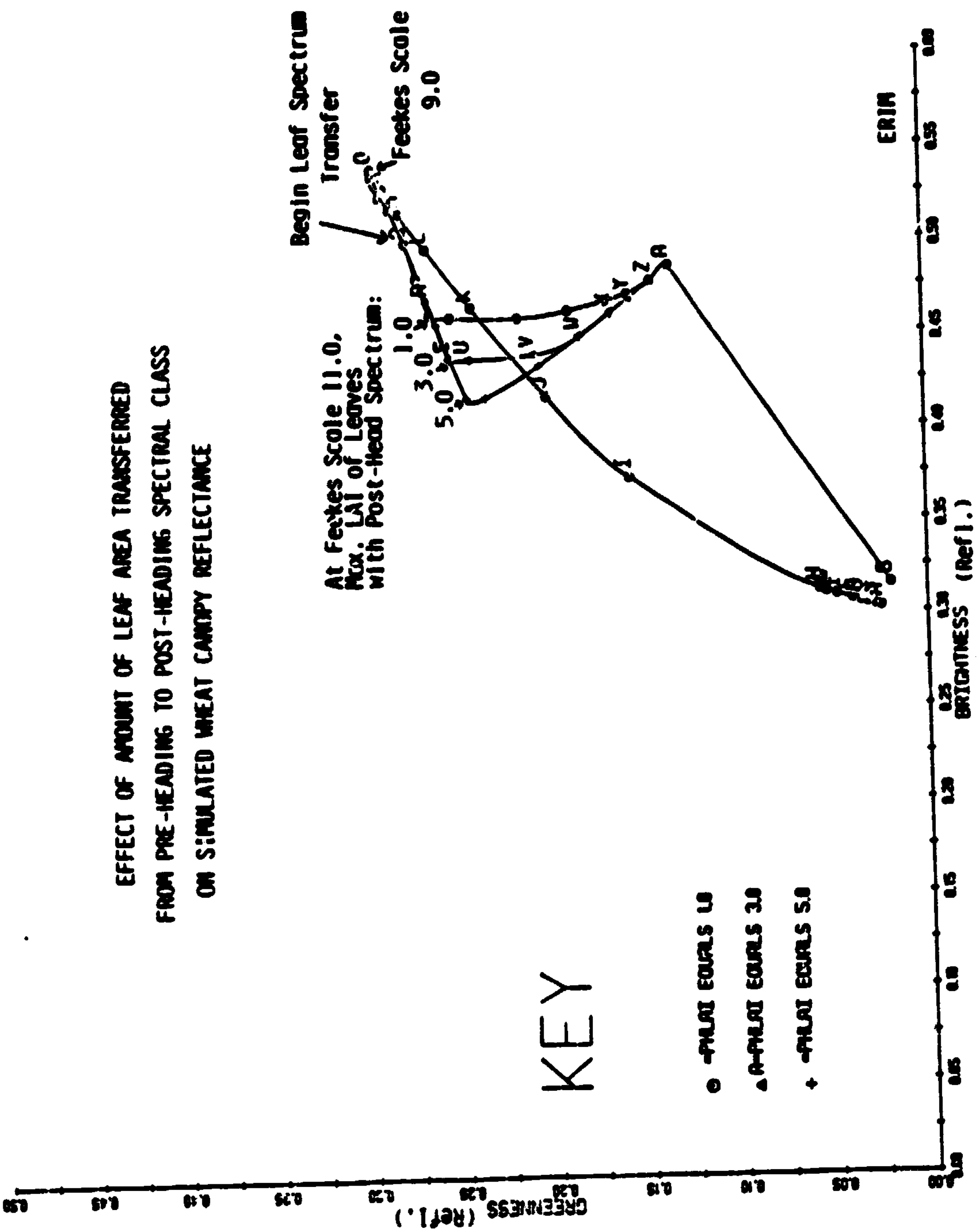

EFFECT OF AMOUNT OF LEAF AREA TRANSFERRED
FROM PRE-HEADING TO POST-HEADING SPECTRAL CLASS
ON SIMULATED WHEAT CANOPY REFLECTANCE

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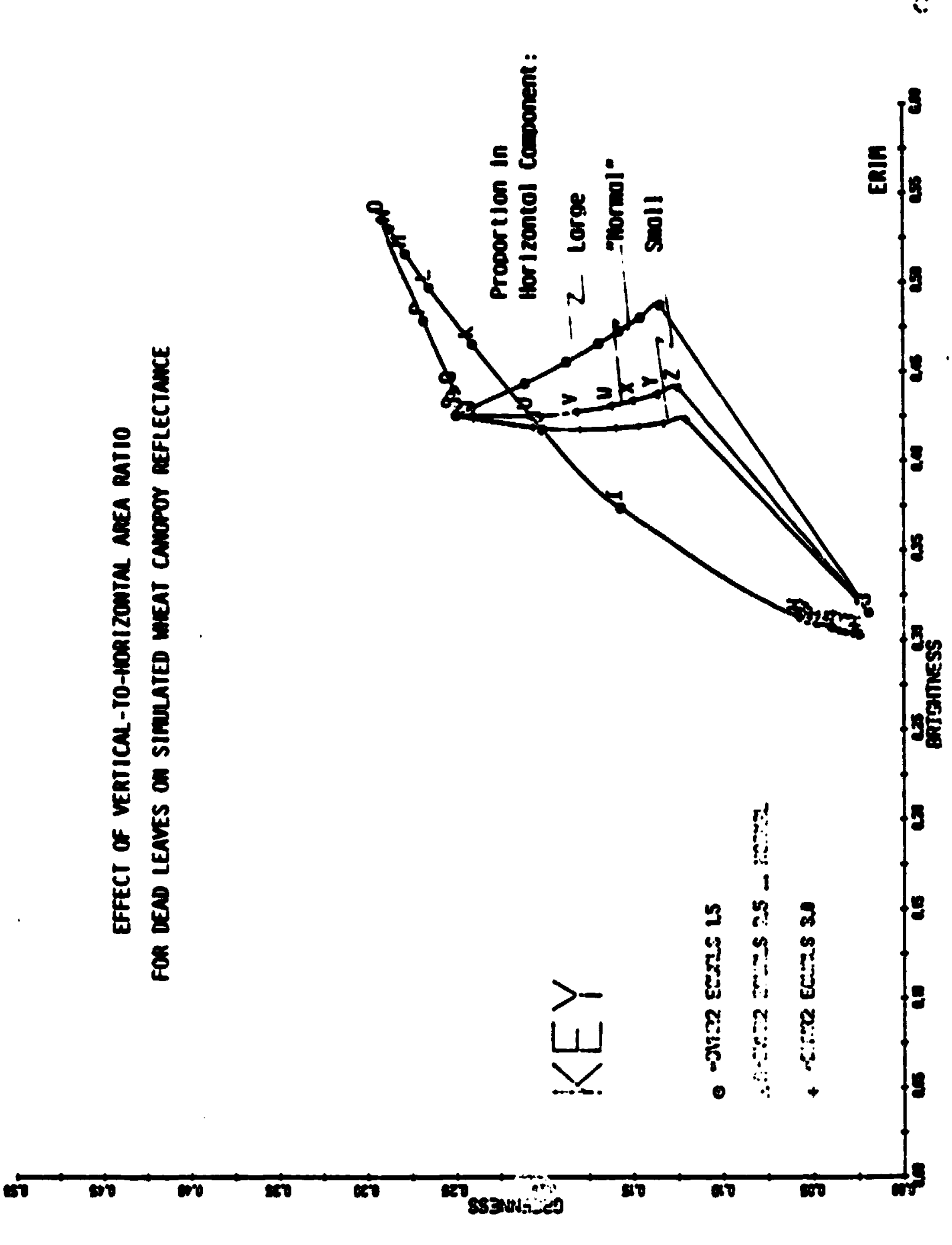

EFFECT OF VERTICAL-TO-HORIZONTAL AREA RATIO
FOR DEAD LEAVES ON SIMULATED WHEAT CANOPY REFLECTANCE

MODELING NEEDS FROM SUPPORTING FIELD RESEARCH

(for all crops of interest)

- Crop Structure vs. Stage of Development and Condition
  - Classes present
  - Amount of each class
  - Orientation of each class (e.g., VHR)
  - Row characterization
- Spectral Characteristics of Crop Components vs. Stage of Development and Condition
  - Spectral reflectance
  - Spectral transmittance
- Measured Reflectance Spectra for Some Situations for Which Above Characteristics are Known

PLANS

- Obtain and Interface Newest Ritchie Model for Wheat/Barley
- Compare Calculations with Field Measurements
- Develop a Capability to Simulate Row Effects in Suits Model
- Initiate Development of a Seed-to-Satellite Module for Soybeans

PERFORMANCE ANALYSIS OF BASELINE CORN AND SOYBEAN PROCEDURE

ERIM/UCB FCPF Corn and Soybean Consortium

Mike Metzler - Task Leader

Presented at

FCPF Quarterly Technical Interchange

July 1981

OUTLINE PRESENTATION

- Procedure Description
- Overall Summary
- Overall Performance
- Error Sources
- Labeling Performance
- Blob Performance
- Unsampled Stratum Effect

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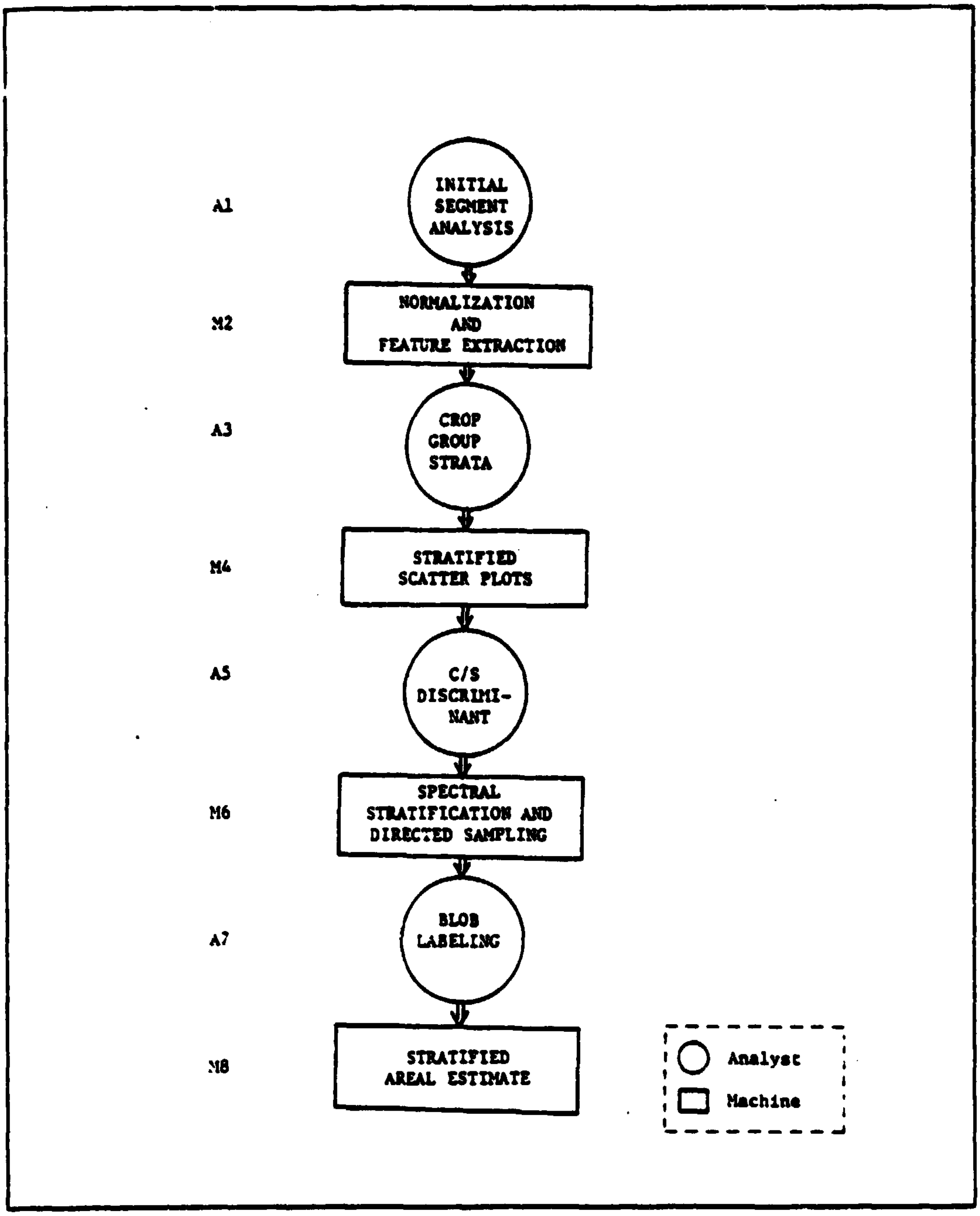
PROCEDURE DESCRIPTION

CHRONOLOGICAL PROCESSING SEQUENCE



C/S BASELINE ESTIMATION APPROACH

	Big Blob Interiors (40%)	Big Blob Boundaries (40%)	Little Blobs (20%)
MACHINE:	Unbiased Sample	Attach Edges to Interiors in an Unbiased Way Label Extension	Spectral Proportion Extension
ANALYST:	Label	---	---

OVERALL SUMMARY OF ANALYSES

STATISTICAL

(Unknown GT Ignored)

	All Available Processings			One Analyst Team ('78 data)		
	$P(\%)$	$(\hat{P}-P)(\%)$	$\frac{\hat{P}-P}{P}(\%)$	$P(\%)$	$(\hat{P}-P)(\%)$	$\frac{\hat{P}-P}{P}(\%)$
Corn	37.60	4.90	13.03	34.38	4.75	13.82
Soy	30.17	-4.46	-14.78	29.98	-8.04	-18.61
Other	32.23	-0.46	-1.40	35.64	3.29	9.23
Summer Crops	67.77	0.45	0.66	64.36	-3.29	-5.11

OVERALL SUMMARY OF ANALYSES

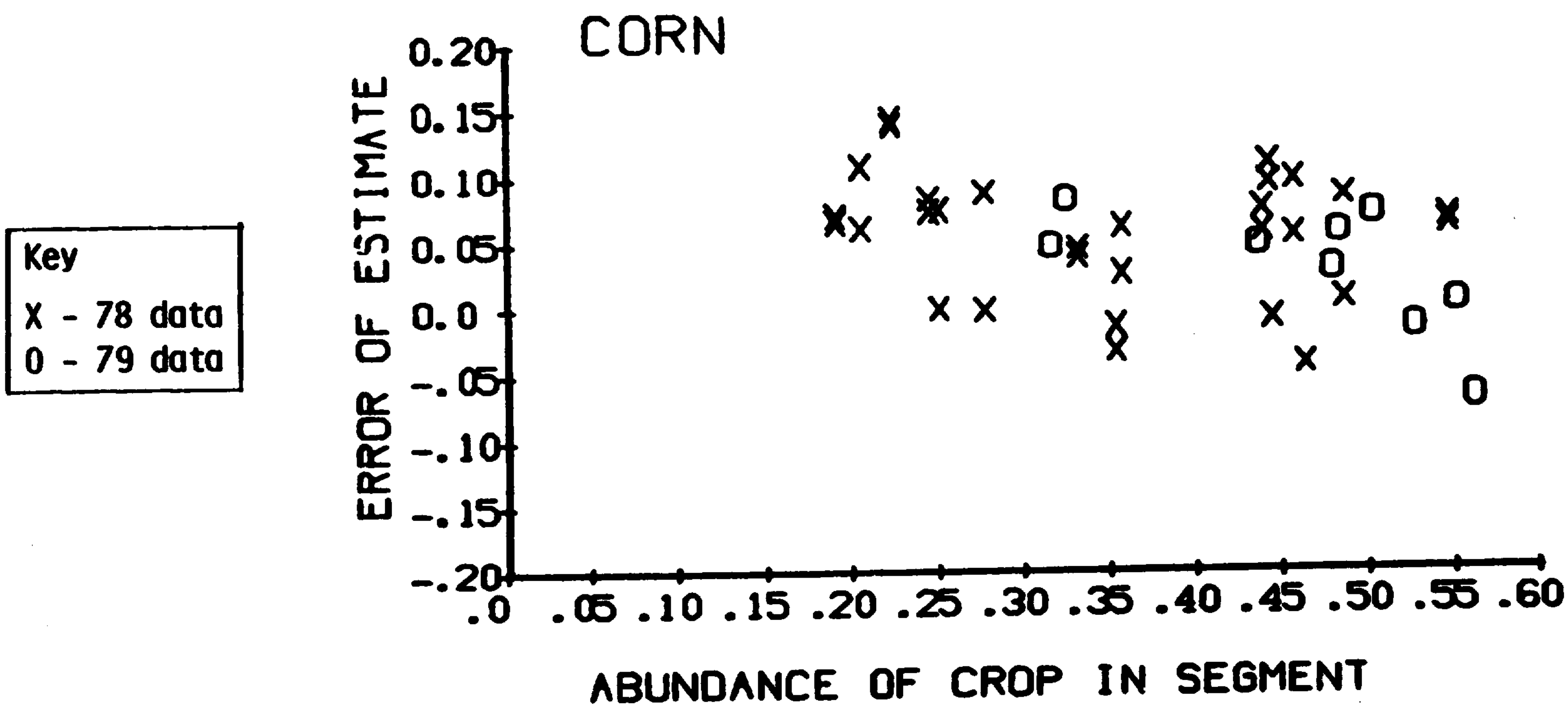
SOURCES OF ERROR

- Labeling Performance
  - Accounts for approximately 80% of soybean estimation error, 60% of corn error
  - Labeling of pure targets accounts for less than one-half of the total labeling error
    - •• labeling inconsistencies and misdetection of crops with two vegetative phases predominanted
    - •• small targets were more error prone
  - Labeling of mixed targets accounts for most of the estimation error attributable to labeling
    - •• only 10% of mixed targets were detected
    - •• inappropriate acquisition selection was a key factor for the presence of mixed targets
- Machine Performance
  - Target definition
    - •• about 22% of all targets were mixed (less than 5/6 pure)
    - •• a tendency to favor corn in assigning edges was detected
  - Machine processing
    - •• unsampled stratum correction only partially corrected the error for corn and other, and increased soy error
    - •• most of the variance in the estimates was attributable to the machine treatment of little blobs

OVERALL PERFORMANCE

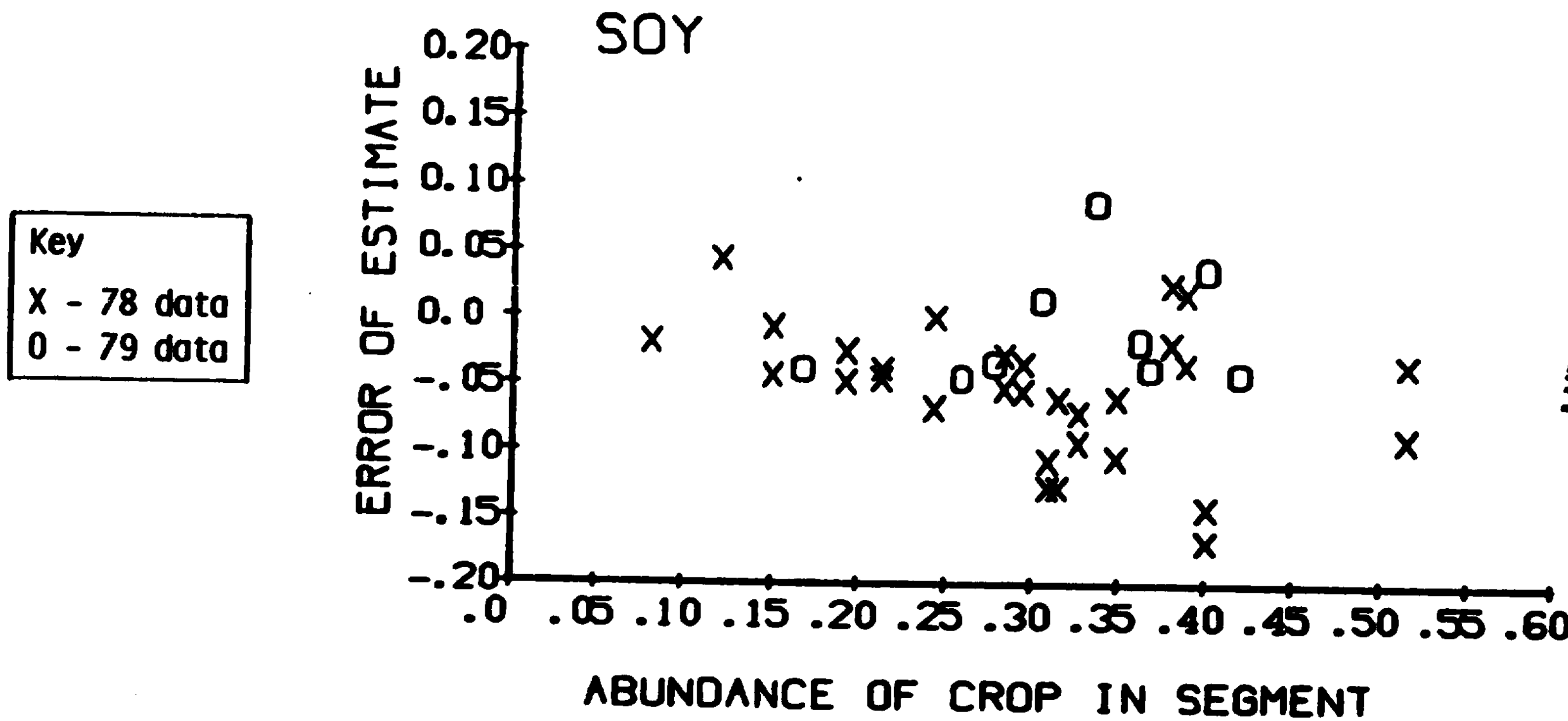
- Corn Acreage is Overestimated, Soybean Acreage Underestimated in 78 Data, Other Underestimated in 79 Data
- Processing Requires One to Two Days Per Segment (Longer End-to-End Depending on Machine and PFC Load)
- Overall Accuracy and Efficiency Point to Need for Refinement and Automation

ERROR* OF ESTIMATE FROM ALL AVAILABLE PROCESSING



*Unknown GT ignored in determining true P.

ERROR* OF ESTIMATE FROM ALL AVAILABLE PROCESSING



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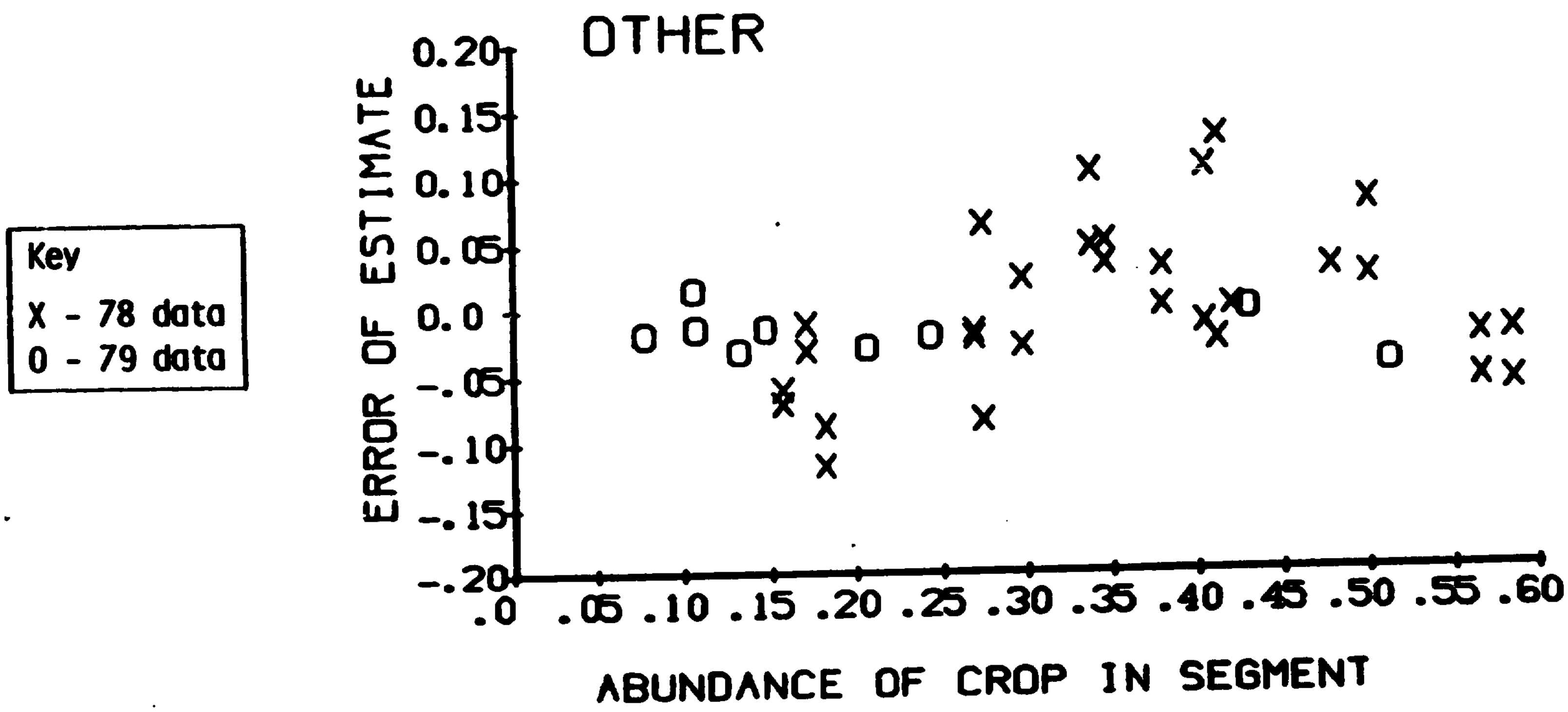
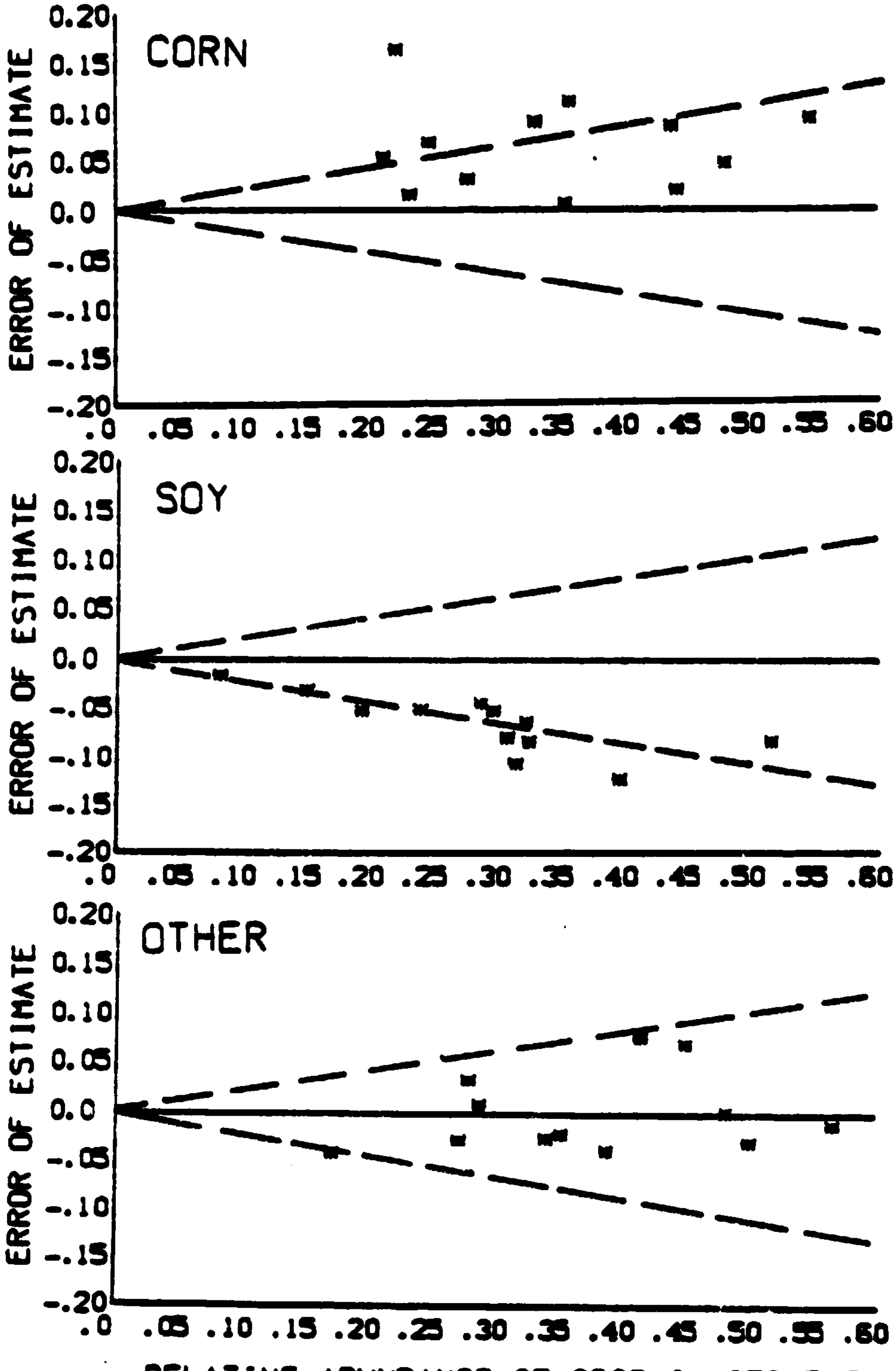
ERROR* OF ESTIMATE FROM ALL AVAILABLE PROCESSING



*Unknown GT ignored in determining true P.

ERROR* OF ESTIMATE FROM ONE ANALYST TEAM



*Unknown GT ignored in determining true P

ERROR SOURCES

- Machine Error Sources
  - Little blobs and interior-to-boundary extention of label
  - Assignment of edges in favor of corn
  - Mixed targets
- Labeling Error Sources
  - Performance on pure targets
  - Detection of mixed targets
- Unknown GT Poses A Problem in Analysis; Treated as 'Other' Where Possible

BREAKDOWN OF ERROR SOURCES

Key		Source
P_2	Unsampled Stratum (little blobs)	Machine
P_3	Interior → Boundary Label Extension	Machine
P_4	Discrete Label for Imperfectly Pure Targets	Machine
P_5	Sampling	Machine
P_6	GT Uncertainty	Ground Truth
P_7	Labeling	Labeiing
P_8	Correction for Unsampled Stratum	Machine

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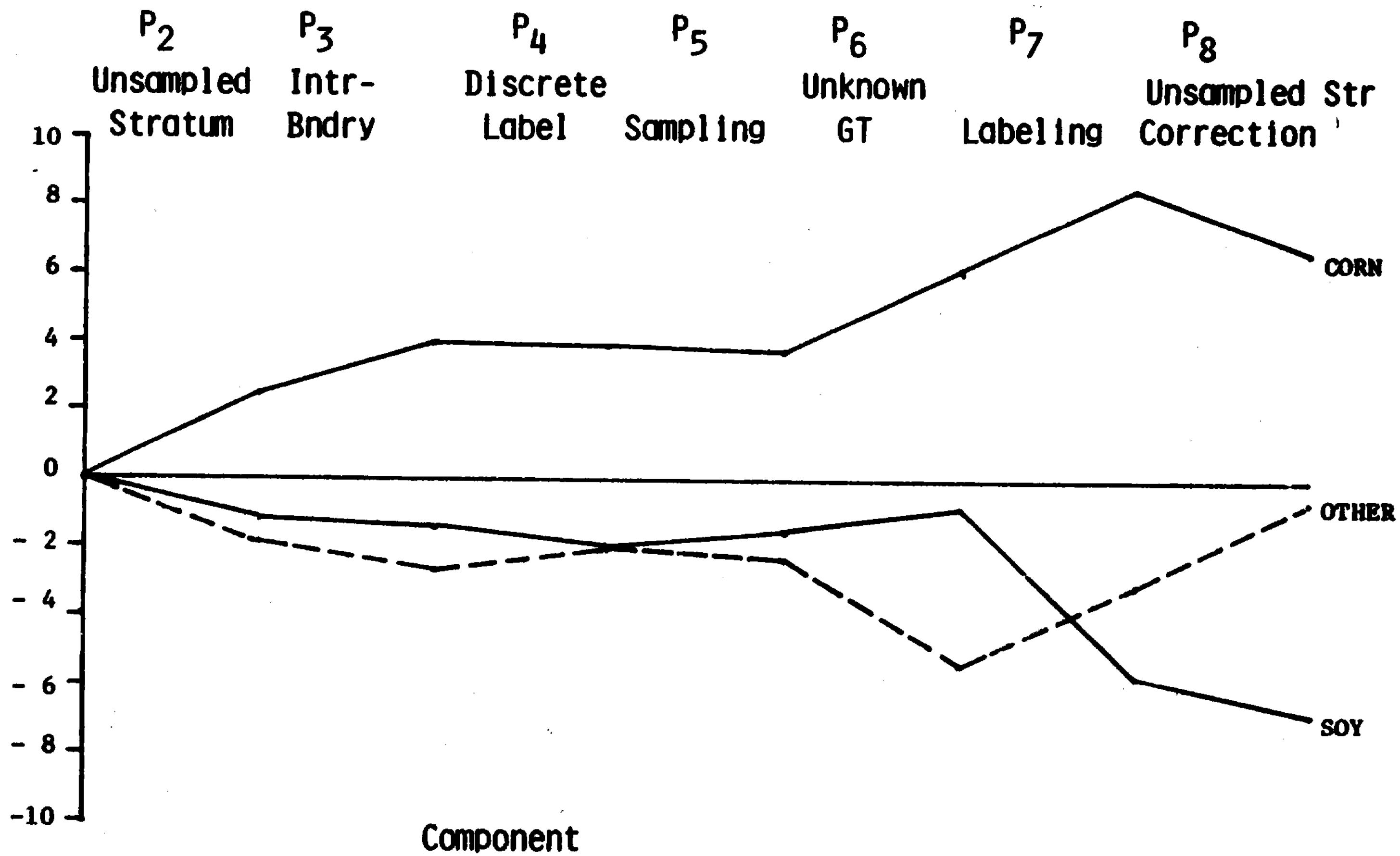
PROGRESSIVE ACCUMULATION OF ERROR BY PROCEDURE COMPONENT



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CONTRIBUTION OF COMPONENTS TO ERROR AND VARIANCE

Relative to Total Error

$$\Delta E_i = \frac{P_i - P_{i-1}}{\hat{P} - P} \times 100$$

where P_i is the estimate at component i

Normalized to Unity

$$N\Delta E_i = \frac{\Delta E_i}{\max(\Delta E_j \text{ for all } j)}$$

Relative to Total Standard Deviation

$$\Delta \sigma_i = \frac{\sigma_i - \sigma_{i-1}}{\sigma} \times 100$$

Normalized to Unity

$$N\Delta \sigma_i = \frac{\Delta \sigma_i}{\max(\Delta \sigma_j \text{ for all } j)}$$

CONTRIBUTION OF COMPONENTS TO TOTAL ERROR*

$\boxed{\Delta E_1}$

	$\hat{P} - P$	Unsampled Stratum Blobs	Intr Bnary	Discrete	Sampling	Unknown GT	Labeling	Unsampled Stratum Correction
Corn	6.62	37.4	23.9	-1.1	-3.2	36.7	35.4	-29.0
Soy	-6.65	16.5	4.6	8.8	-7.3	-2.1	83.2	15.0
Other	-0.60	304.3	133.0	-106.5	45.0	518.4	-394.0	-400.3

$\boxed{N\Delta E_1}$

	$\hat{P} - P$	Unsampled Stratum Blobs	Intr Bnary	Discrete	Sampling	Unknown GT	Labeling	Unsampled Stratum Correction
Corn		1.00	0.64	-0.03	-0.09	0.98	0.95	-0.78
Soy		0.20	0.06	0.11	-0.09	-0.26	1.00	0.19
Other		0.59	0.26	-0.21	0.03	1.00	-0.76	-0.77

*Unknown GT is "other"

CONTRIBUTION OF COMPONENTS TO TOTAL STANDARD DEVIATION

	σ	Unsampled Stratum	$\boxed{\Delta\sigma_1}$ Intr-Bndry	Discrete	Sampling	Unknown GT	Labeling	Unsampled Stratum Correction
Corn	4.50	39.1	16.5	3.7	11.1	18.4	18.1	-7.7
Soy	3.79	57.5	-2.5	4.7	24.6	5.8	-0.4	10.3
Other	6.44	26.4	11.6	5.0	17.7	22.4	6.8	10.1

		$\boxed{N\,\Delta\sigma_1}$					
Corn	1.00	0.42	0.09	0.31	0.47	0.46	-0.20
Soy	1.00	0.04	0.08	0.43	0.10	0.01	0.18
Other	1.00	0.44	0.19	0.67	0.85	0.26	0.38

SUMMARY OF ERROR SOURCES

$$\boxed{\sum_j N\Delta E_j}$$

	Corn	Soy	Other
Machine	0.74	0.47	-0.10
Labeling	0.95	1.00	-0.76
GT Uncertainty	0.98	-0.26	1.00

$$\boxed{\sum_j N\Delta \sigma_j}$$

	Corn	Soy	Other
Machine	1.62	1.73	2.68
Labeling	0.46	0.01	0.26
GT Uncertainty	0.47	0.10	0.85

LABELING PERFORMANCE

- Pure Target Accuracy Comparable to that Exhibited by Previous LACIE/LEMSCO Labeling Logic
- Key Sources of Error on 'Pures' Included:
  - Inconsistent tracking of labeling logic
  - Two vegetation cycles
  - Small targets
- Detection and Labeling of Mixed Targets Resulted in Significant Estimation Error

C/S BASELINE LABELING ACCURACY

BLOBS $\geq$ 5/6 PURE (830 out of 1112)

Weighted by BLOB Size

		Label		
		C	S	O
GT	C/	95.86	0.39	3.75
	S/	4.13	87.59	8.29
	O/	6.95	0.84	92.20

EFFECT OF BLOB PURITY

ON LABELING ACCURACY

Weighted Decisions

$\geq$ 5/6 Pure

		Label		
		C	S	O
GT	C/	95.86	0.39	3.75
	S/	4.13	87.59	8.29
	O/	6.95	0.84	92.2

$\geq$ 2/3 Pure

		Label		
		C	S	O
GT	C/	94.18	0.46	5.36
	S/	5.29	85.57	9.13
	O/	8.17	1.19	90.64

EFFECT OF BLOB SIZE

ON LABELING ACCURACY

BLOBs $\geq$ 5/6 Pure

Weighted

		Label		
		C	S	O
GT	C/	95.86	0.39	3.75
	S/	4.13	87.59	8.29
	O/	6.95	0.84	92.2

Unweighted

		Label		
		C	S	O
GT	C/	91.42	0.61	7.98
	S/	4.49	81.97	13.54
	O/	7.98	1.24	90.78

ERROR SOURCES IN LABELING

	Corn (absolute %)	Soybean (absolute %)
Total Absolute Error	6.62	-6.65
1. Attributable to Labeling	1.84 to 3.55	-3.53 to -4.41
(a) Attributable to Mis-labeled Pures*	29.5%	46.9%
(b) Attributable to Mixed Targets	70.5%	53.1%

*of total labeling error

EFFECT OF PURITY ON CROP PROPORTION ESTIMATES USING SAMPLED BLOBS FROM 11 SEGMENTS

Analyst Mixture Detection Rate: 10%

		GT*	Analyst	% of Total Error	% of Scene
All Blobs	Corn	44.64	48.35	---	100
	Soybeans	25.19	20.14		
	Other	30.17	31.52		
Blobs $\geq$ 5/6 Pure	Corn	44.32	47.00	29.5	78.07
	Soybeans	25.43	22.23	46.9	
	Other	30.25	30.77	30.1	
Blobs $<$ 5/6 Pure	Corn	45.79	53.16	70.5	21.94
	Soybeans	24.34	12.68	53.1	
	Other	29.87	34.16	69.9	

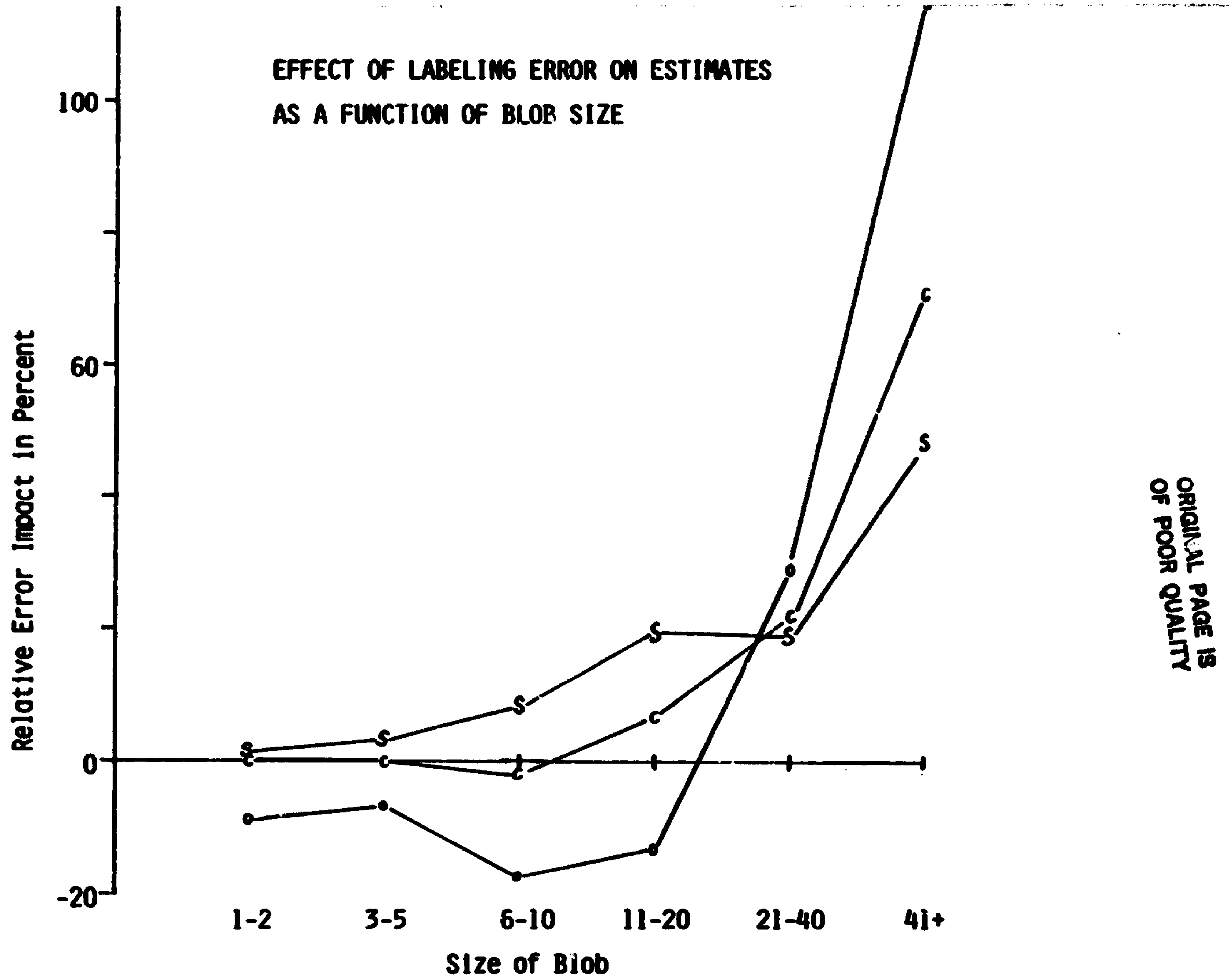
*Among sampled blobs only

MISLABELED PURE BLOBS FROM 11 SEGMENTS RELATIVE TO ZONE OF THE CORN/SOYBEAN DISCRIMINANT

1. "A" Zone Predominates. 63.11% of All Mislabeled Blobs are from this Zone
2. "D" Zone Accounts for 19.67%
3. "B" and "C" Zones Together Account for 17.21%

MISLABELED BLOB SIZE DISTRIBUTION

	Interior Pixels					
	1 - 5	6 - 10	11 - 20	21 - 30	31 - 40	41 - 100
Percentage of Blobs Mislabeled Per Pixel Group	58.77	18.42	14.91	6.14	0.89	1.75


EFFECT OF LABELING ERROR ON ESTIMATES
AS A FUNCTION OF BLOB SIZE
100
60
0
-20
Relative Error Impact in Percent
1-2
3-5
6-10
11-20
21-40
41+
Size of Blob

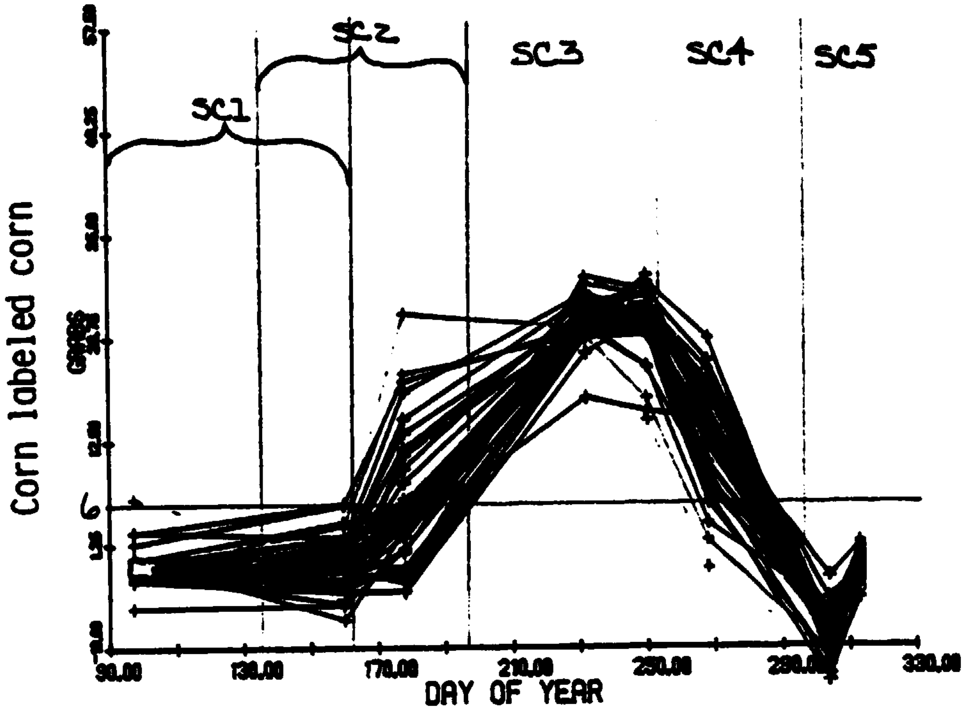
ANALYSIS OF ERRORS IN LABELING PURE BLOBS

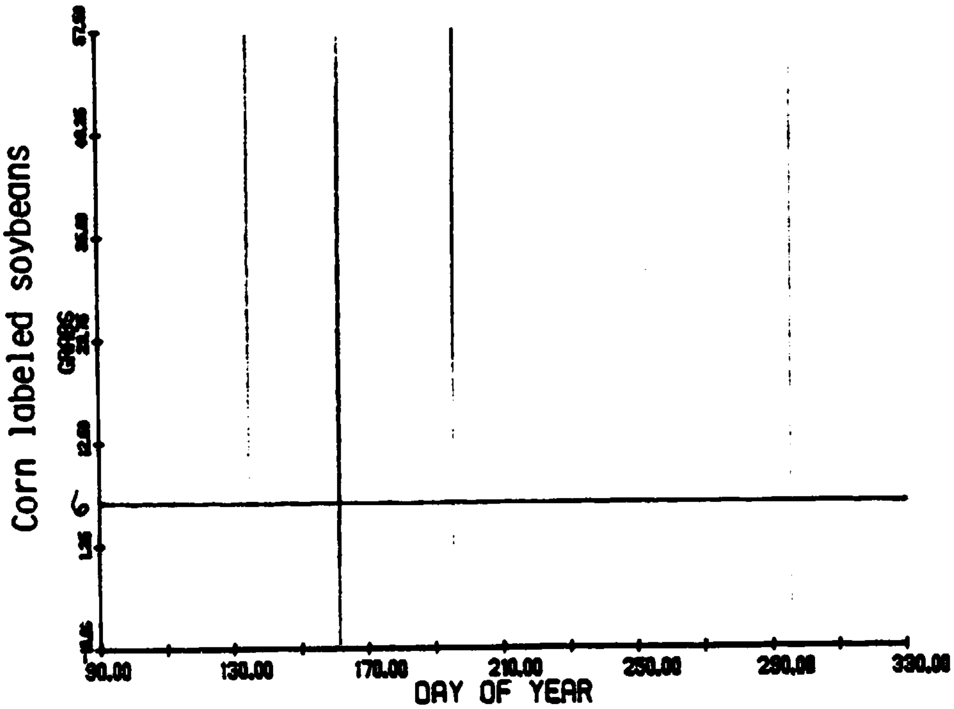
	% of Error	% of Total Error
Analyst Error (A.I. failed to heed logic)		49.6%
• Couldn't track analyst	46%	(22.8%)
• Probably due to double peaks	(30%)	
• Misc. or no clue to error	(16%)	
• Double peaks in profile (?22) (volunteer veg. or double cropping)	20%	(10.0%)
• Determination of smoothness of profile and number of vegetated phases (?12, 13, 16)	18%	(9.0%)
• Comparison of profiles (?31)	4%	(2.0%)
• Inhomogeneous vs. homogeneous fields (ignoring roads) (?7, 25)	5%	(2.4%)
• Confusing TPC patterns (?5, 6)	5%	(2.4%)
• Analyst wrote down wrong answer	2%	(1.0%)

ANALYSIS OF ERRORS IN LABELING PURE BLOBS (Continued)

	% of Error	% of Total Error
Logic or Ground Truth 'Errors' (A.I. correctly followed logic)		47.8%
• No ground truth - probably correctly labeled by the analyst	24%	(11.5%)
• Inseparable or anamalous profiles	50%	(23.9%)
• Misregistration, mixed pixels, or incorrect ground truth	19%	(9.1%)
• Miscellaneous	7%	(3.3%)
Unable to Determine Source of Error		2.6%

SEGMENT 842


Corn labeled corn
GRABS
SC1
SC2
SC3
SC4
SC5
6
DAY OF YEAR
90.00
130.00
170.00
210.00
250.00
290.00
330.00


Corn labeled soybeans
GRABS
6
DAY OF YEAR
90.00
130.00
170.00
210.00
250.00
290.00
330.00

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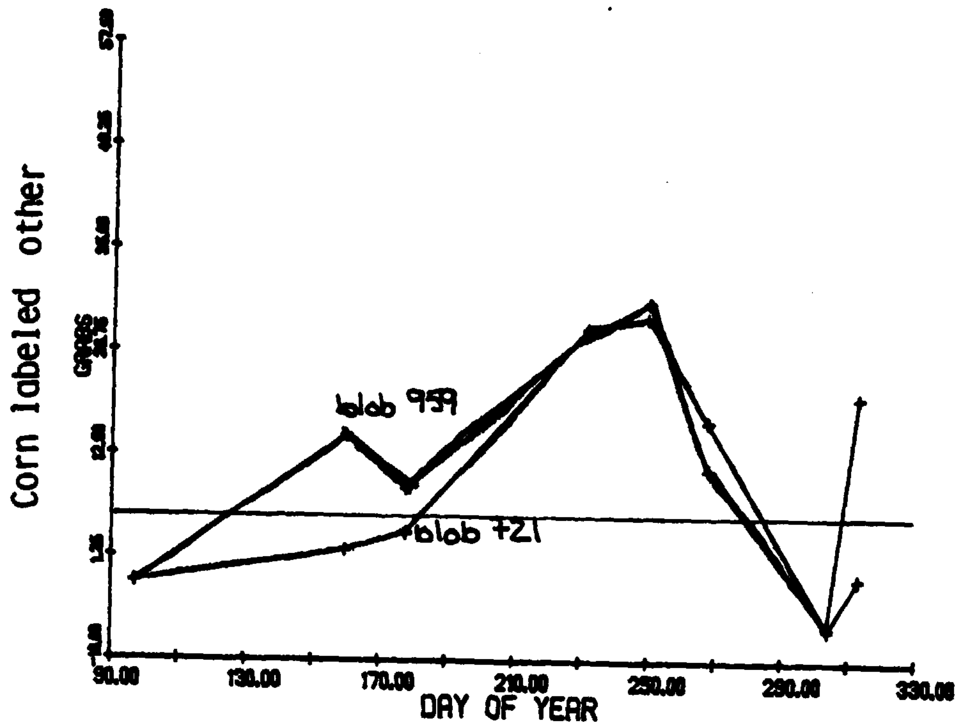
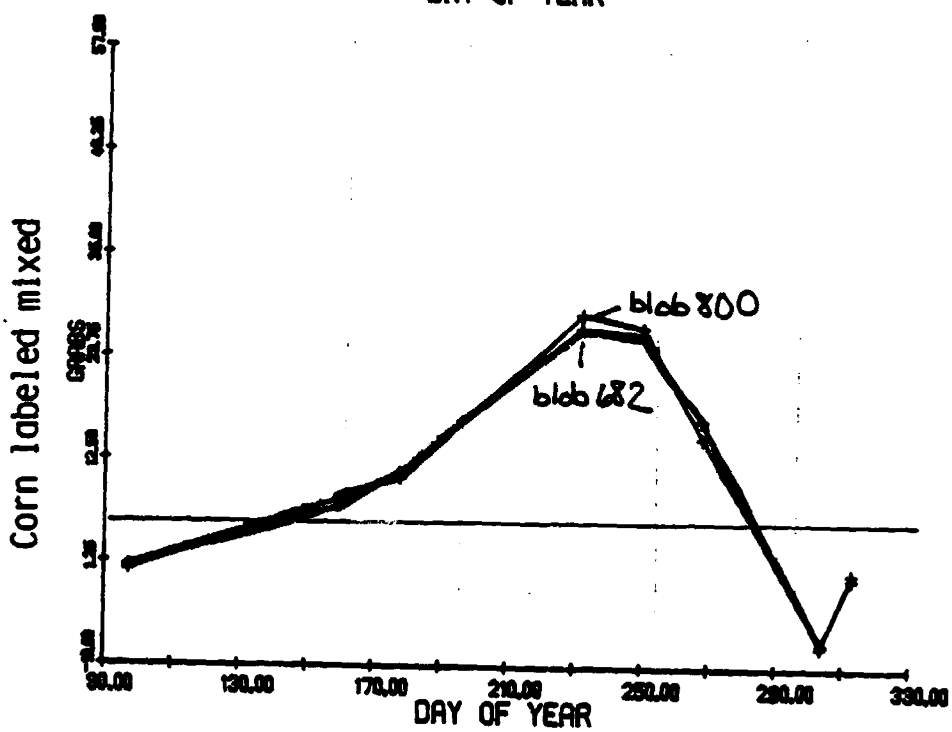
SEGMENT 842





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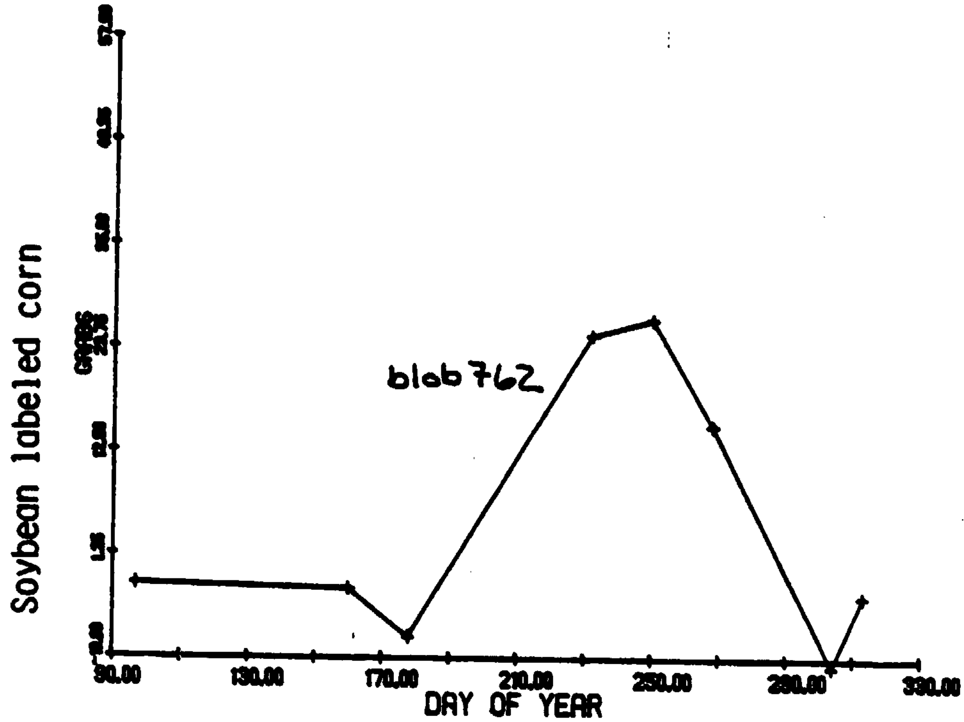

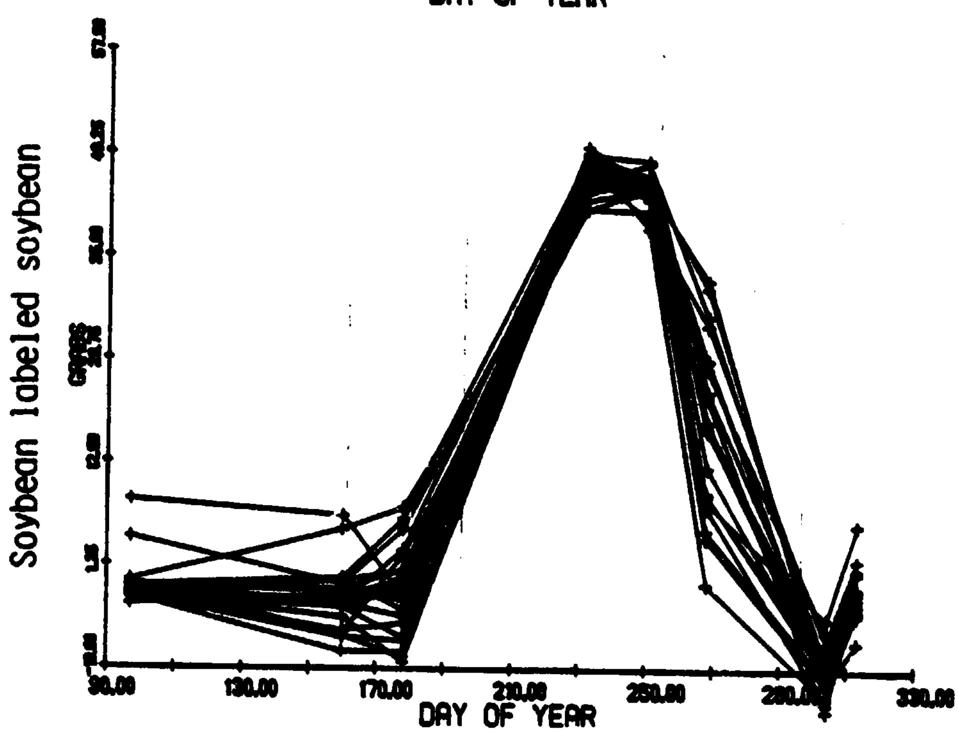

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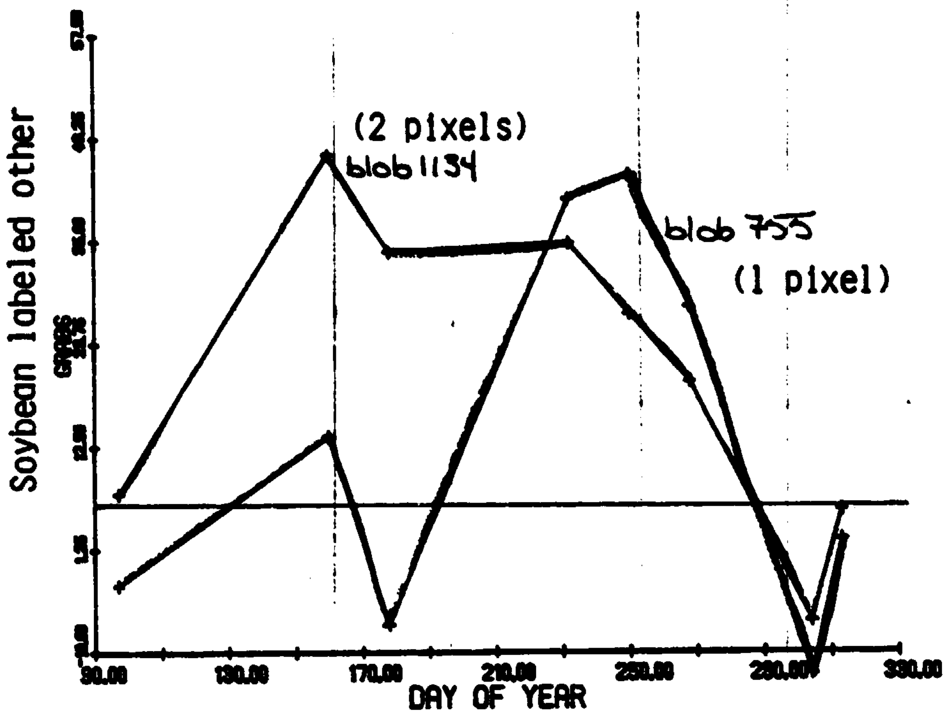
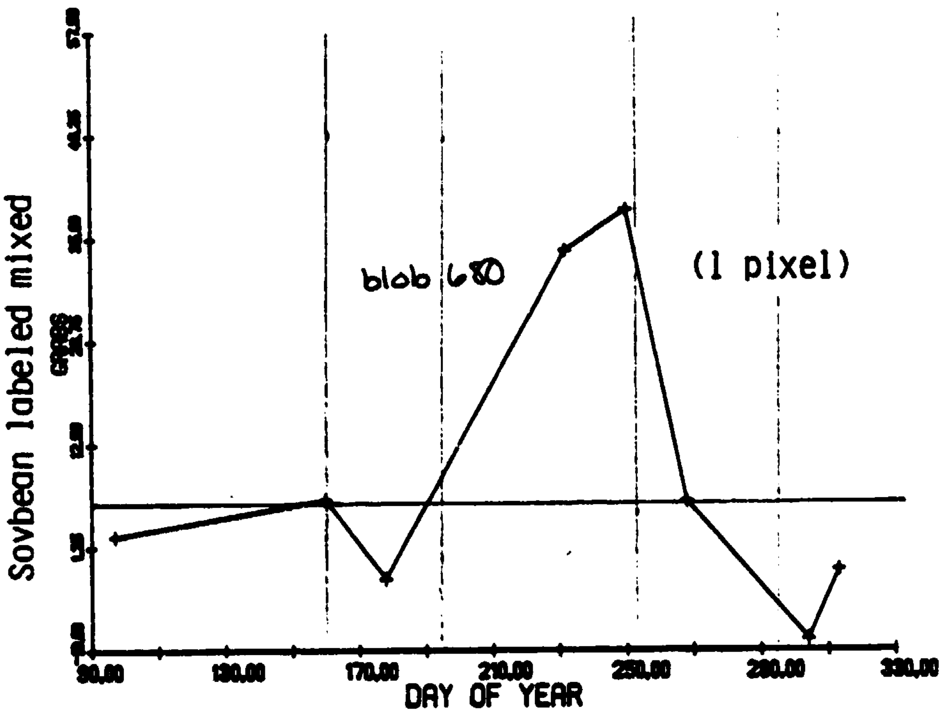
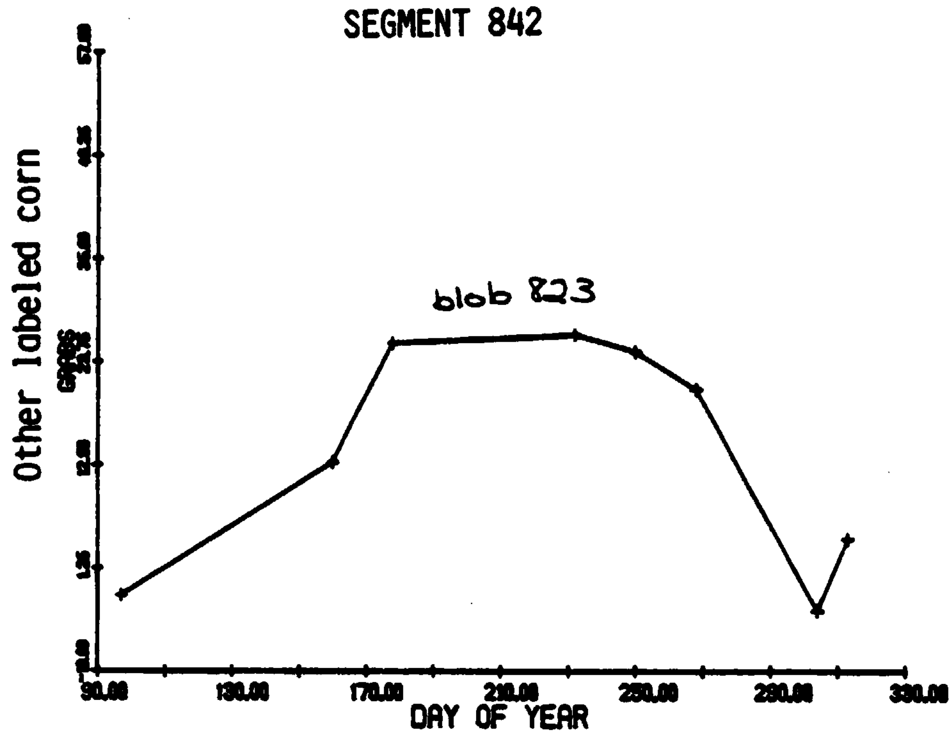
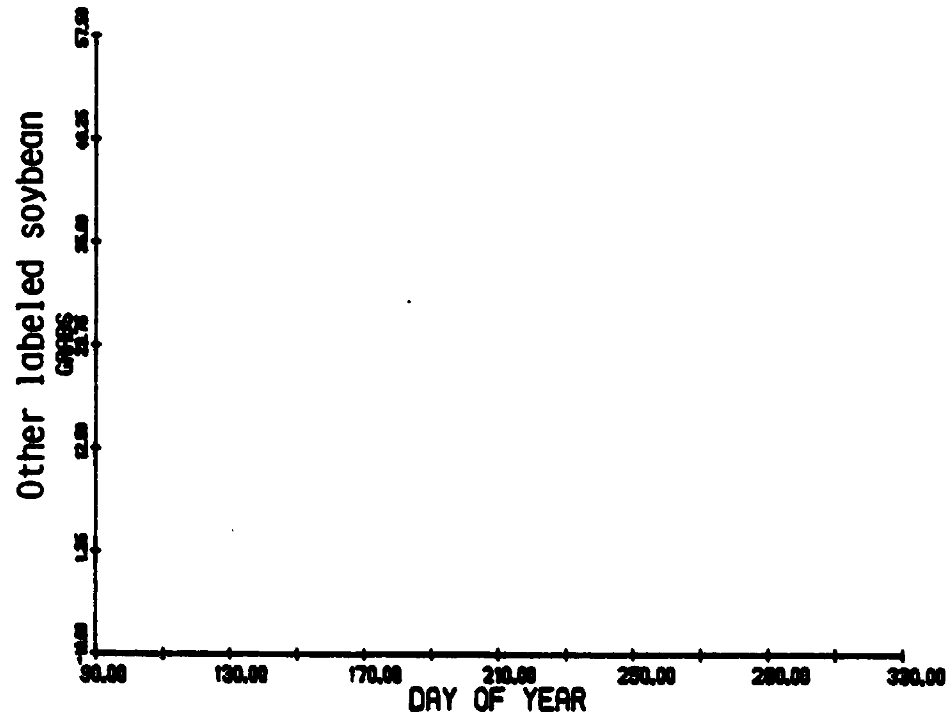
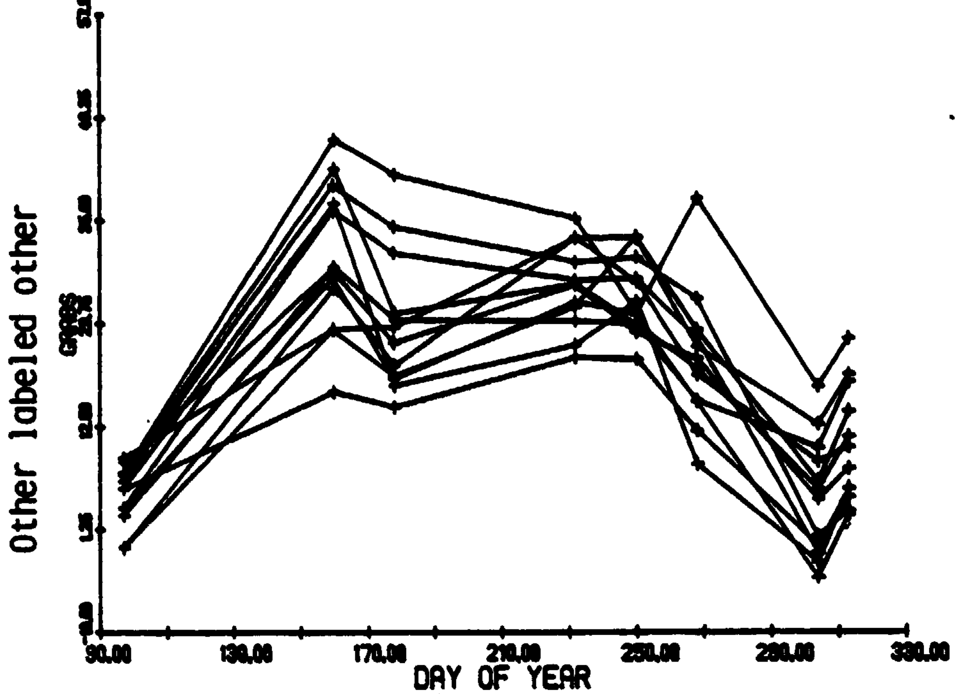


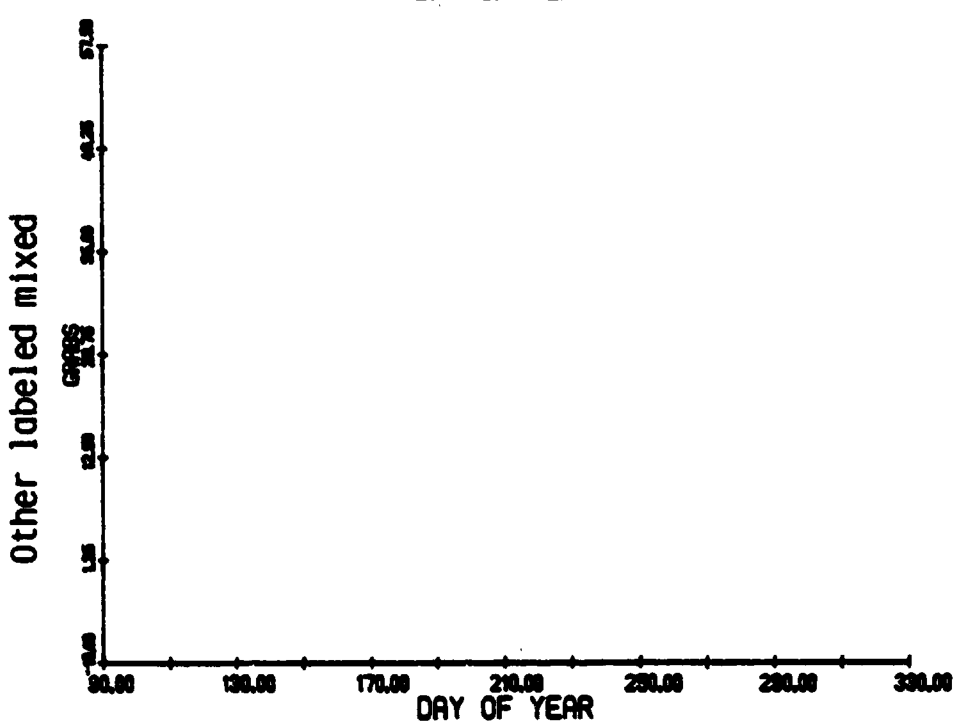



SEGMENT 842
Other labeled corn
GRABS
DAY OF YEAR
90.00
130.00
170.00
210.00
250.00
290.00
330.00
blob 823


Other labeled soybean
GRABS
DAY OF YEAR
90.00
130.00
170.00
210.00
250.00
290.00
330.00

SEGMENT 842


Other labeled other
90.00
130.00
170.00
210.00
250.00
290.00
330.00
DAY OF YEAR


Other labeled mixed
90.00
130.00
170.00
210.00
250.00
290.00
330.00
DAY OF YEAR

BLOB PERFORMANCE

- Purpose is to Form 'Pure' Targets
- 79% of All Big Blobs Formed were at Least 5/6 Pure and Averaged 97% Pure
- However, 21% of the Big Blobs That were Mixed Significantly Impacted Analyst Labeling Performance
- There Existed a Consistent Tendency to Favor Corn in Attaching Edges to Blob Interiors

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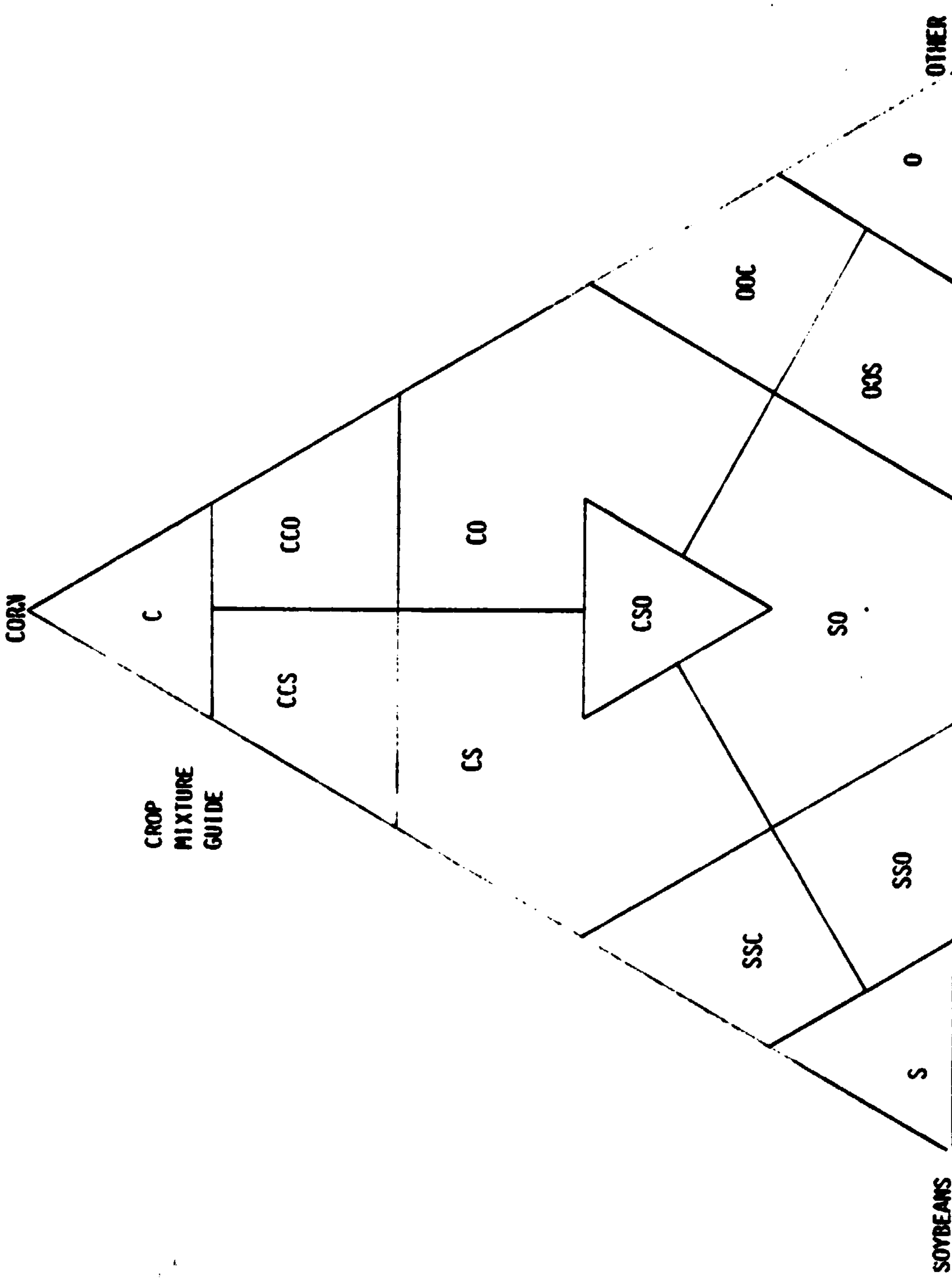

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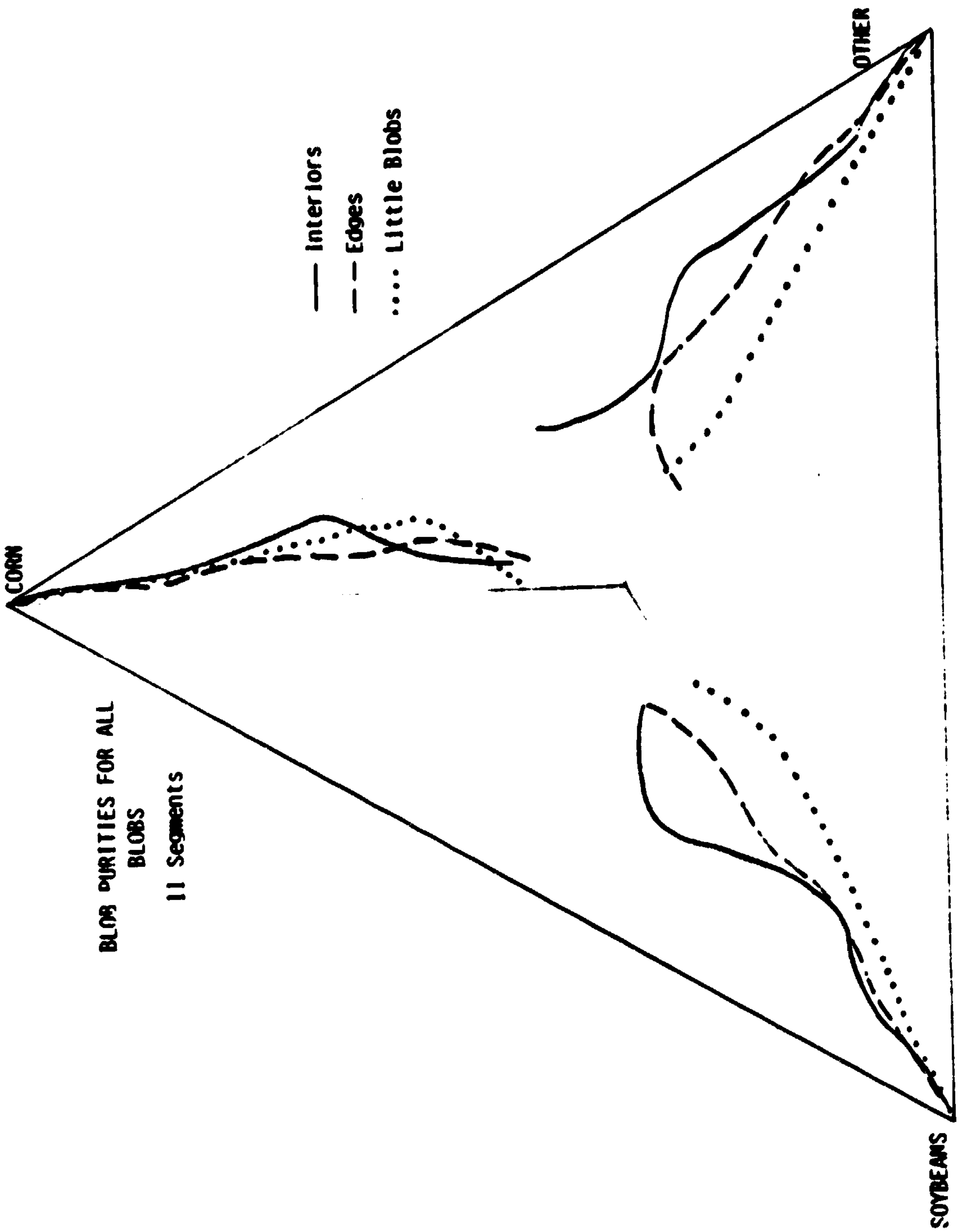

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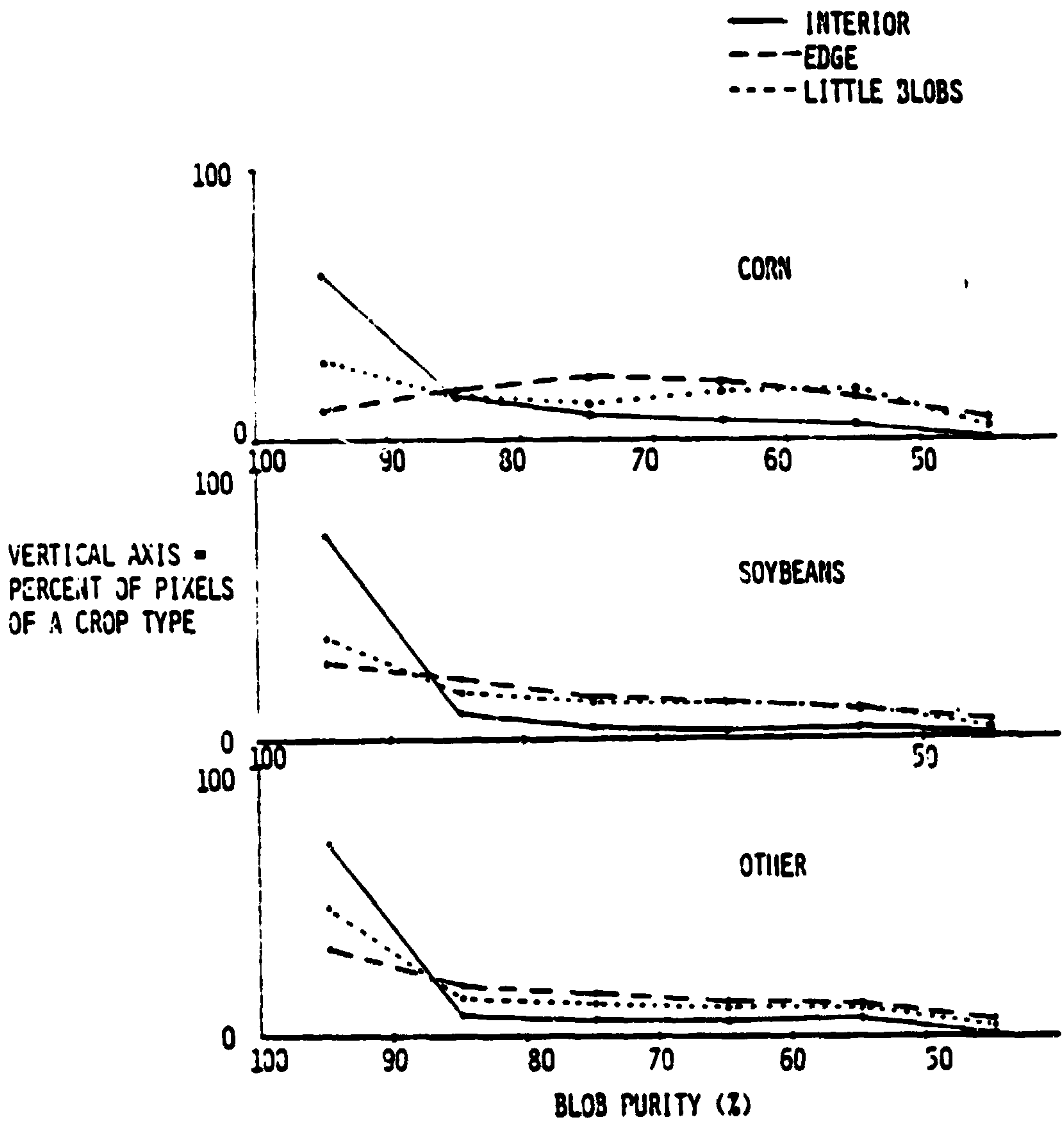
BLOB PURITIES FOR 11 SITES
(PERCENT OF PIXELS OF A CROP TYPE VS. PURITY OF THE BLOBS
IN WHICH THEY ARE LOCATED)



CROP COMPOSITION OF 5/6 PURE BLOBS

	Interior only GT			Interior and Edge GT		
	C	S	0	C	S	0
C	95.7	1.5	2.8	80.8	6.7	12.5
S	1.0	97.7	1.2	5.4	89.3	5.2
0	1.4	0.8	97.7	6.7	4.6	88.7

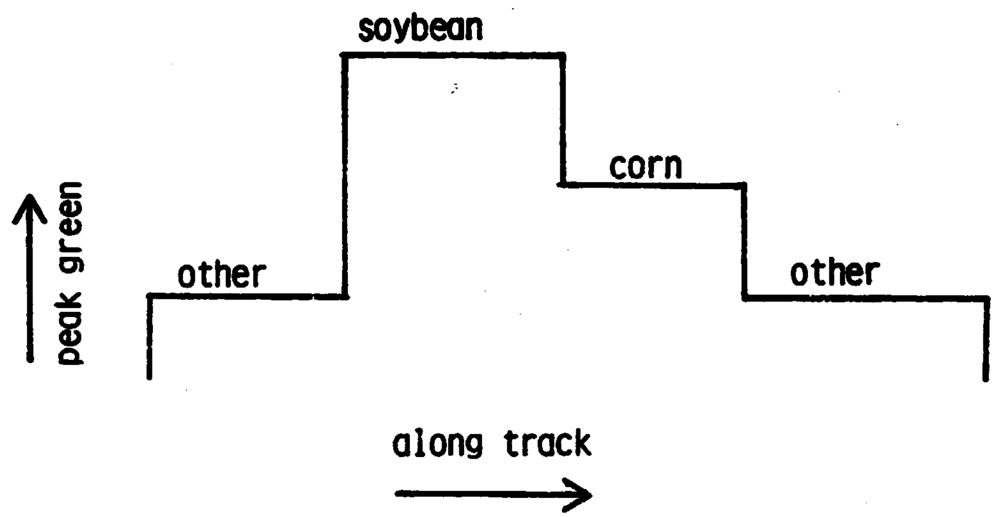
BOUNDARY TO INTERIOR PURITY RATIOS -
11 SEGMENTS FOR BLOBS $\geq$ 5/6 PURE, UNKNOWN < 50%

NUMBER OF INTERIOR PIXELS

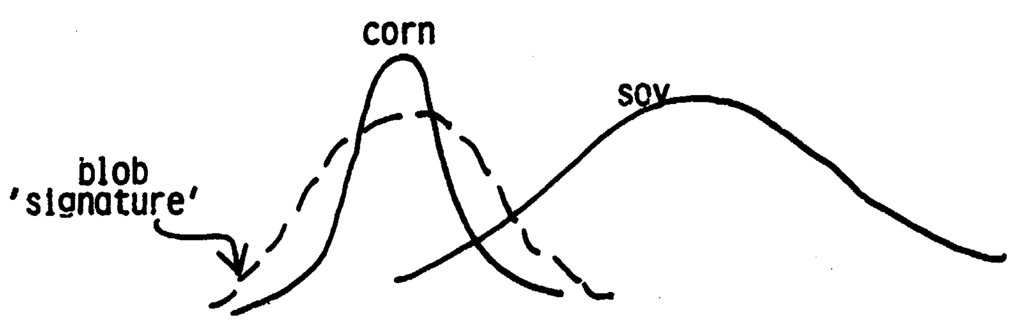
	1 - 2	3 - 5	6 - 10	11-20	21-40	41-100	>100
CORN	0.732	0.759	0.781	0.788	0.770	0.785	0.822
SOYBEANS	0.828	0.847	0.846	0.827	0.857	0.846	0.958
OTHER	0.830	0.855	0.868	0.861	0.875	0.901	0.890

EXPLANATION OF EDGE BIAS IN BLOBING

1. Spectral Relationship Among Crops



2. Variance Characteristics of Crops

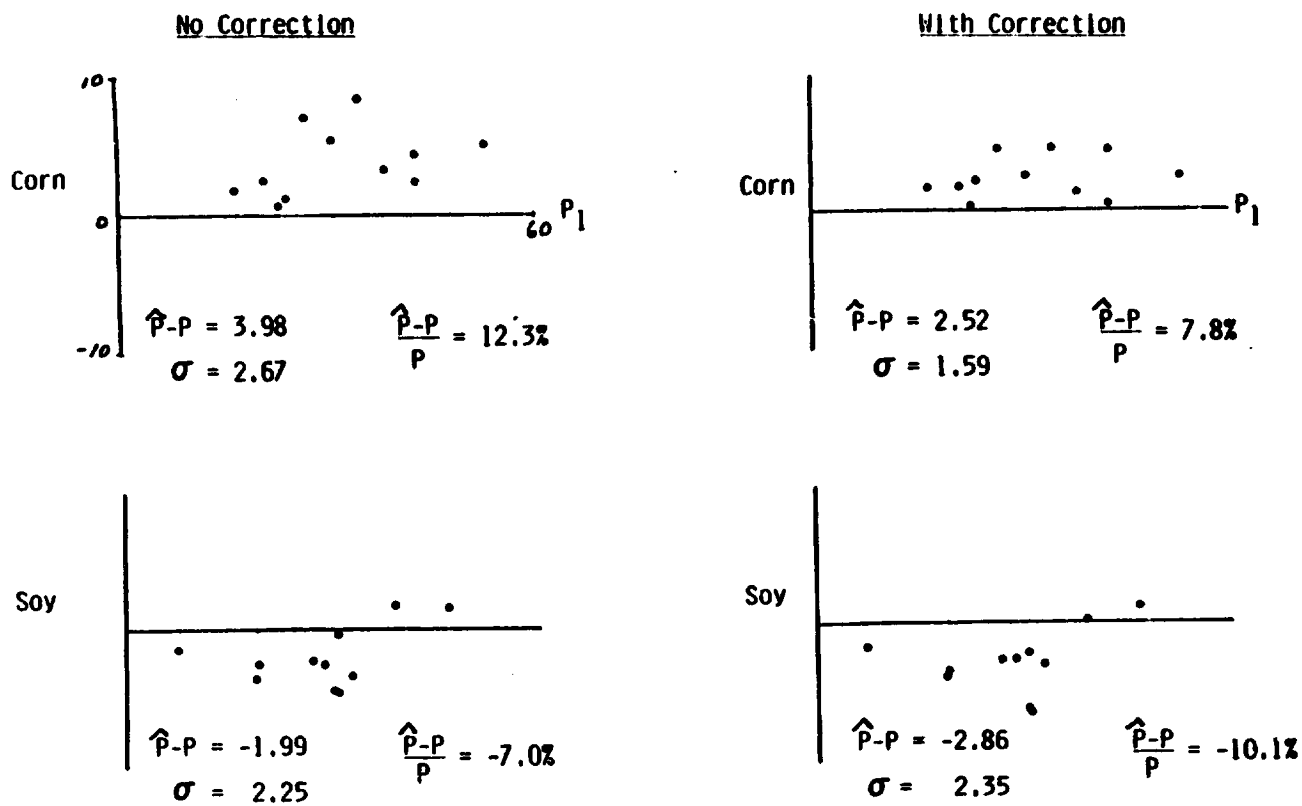


UNSAMPLED STRATUM EFFECT

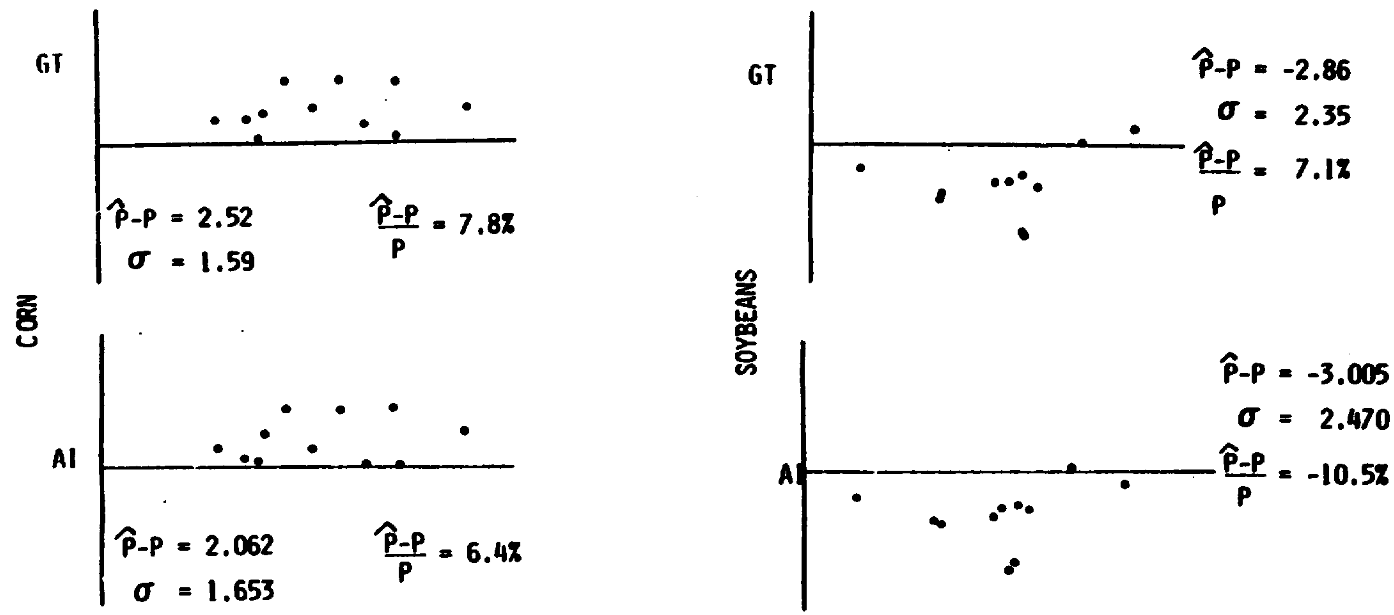
- Extension of Estimate to Unsampled Stratum
    - showed improvements for corn and other
    - hurt soybean estimate a little
- Additional Improvements are Called For

PERFORMANCE OF BASELINE PROCEDURE CORRECTION

USING GROUND TRUTH W/O SAMPLING



ROBUSTNESS OF CORRECTIONS IN PRESENCE OF
ANALYST LABELS



OVERALL SUMMARY OF ANALYSES

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  - Accounts for approximately 80% of soybean estimation error, 60% of corn error
  - Labeling of pure targets accounts for less than one-half of the total labeling error
    - •• labeling inconsistencies and misdetection of crops with two vegetative phases predominated
    - •• small targets were more error prone
  - Labeling of mixed targets accounts for most of the estimation error attributable to labeling
    - •• only 10% of mixed targets were detected
    - •• inappropriate acquisition selection was a key factor for the presence of mixed targets
- Machine Performance
  - Target definition
    - •• about 22% of all targets were mixed (less than 5/6 pure)
    - •• a tendency to favor corn in assigning edges was detected

OVERALL SUMMARY OF ANALYSES (Continued)

SOURCES OF ERROR

- Machine processing
  - •• unsampled stratum correction only partially corrected the error for corn and other, and increased soy error
  - •• most of the variance in the estimates was attributable to the machine treatment of little blobs

MODIFICATIONS TO BASELINE PROCEDURE

ERIM/UCB FCPF Corn and Soybean Consortium

Mike Metzler - Task Leader

Presented at

FCPF Quarterly Technical Interchange

July 1981

IN THIS TALK WE WILL DISCUSS

- What we are Changing Now
- Why These Changes were Selected
- What Effects we Think These Changes Will Have
- What we Expect to do, Given More Time

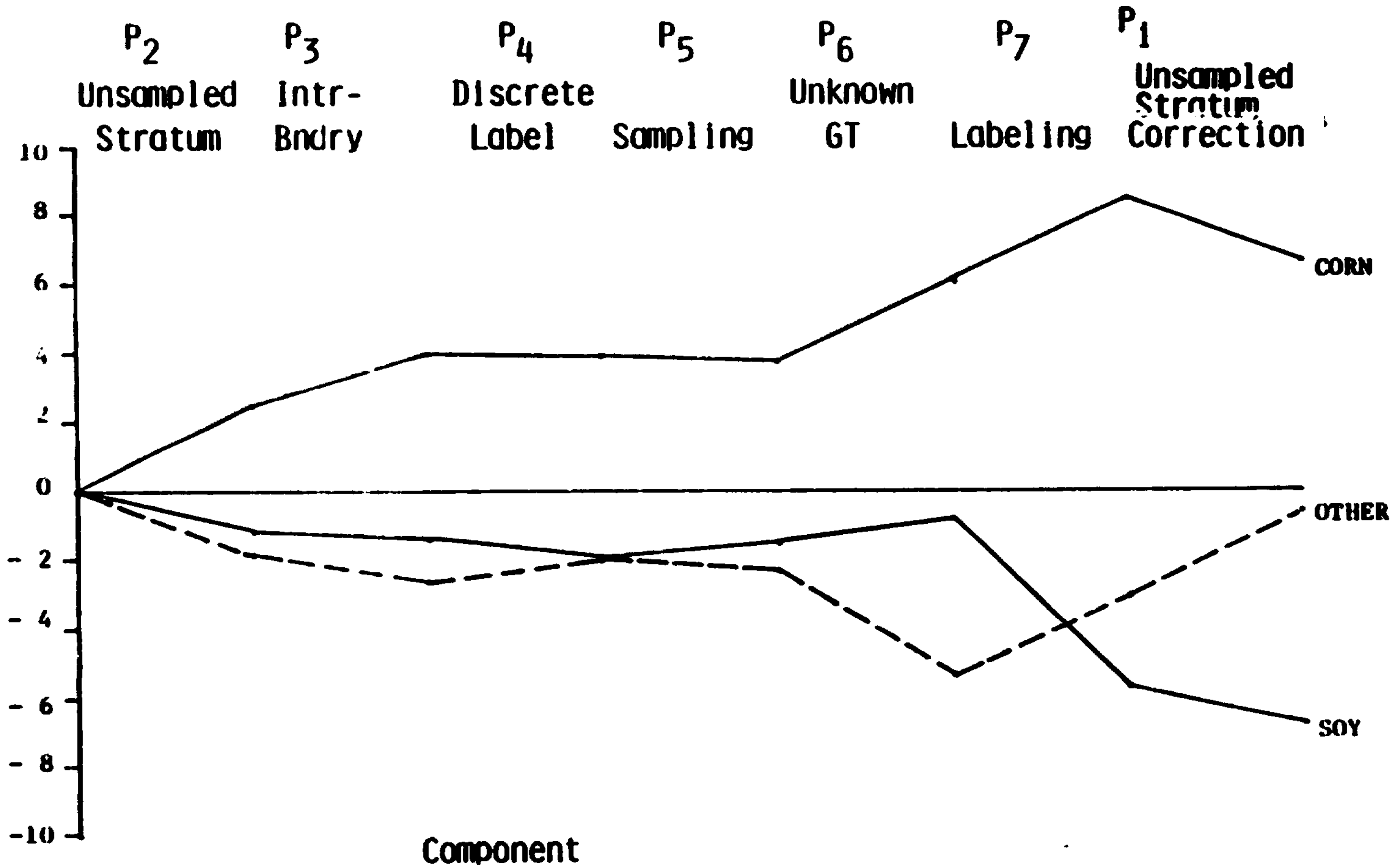
OUTLINE

- General Approach
- Near-Term Changes
  - In response to observed error
  - Related to current procedure
  - List of near-term changes
  - Description of the near-term changes
  - Expected effects
- The Longer Term

GENERAL APPROACH

- Overall Objectives
    - minimize bias
    - minimize variance
    - minimize cost (max efficiency)
    - maximize learning
- Short Term Objectives
    - minimize bias
    - meet deadline
    - (meet other objectives only if low-investment/ high-return actions can be carried out)
- Medium Term Objectives
    - better researched modifications
    - more careful validation

PROGRESSIVE ACCUMULATION OF ERROR BY PROCEDURE COMPONENT



ERROR SOURCES

Source of Error*	RMS Magnitude	
Labeling	6.5%	mixtures 4% pures 2.5%
(Unknown G.T.)	4.0%	
Unsampled Stratum	2.2%	
Big Blob Boundaries	1.8%	
Discrete Labels	0.9%	
Sampling	0.6%**	
Sum	16.0	
Total Error	9.4	(some compensation occurred)

*bias
**unbiased by theorem; measurement of bias has variance

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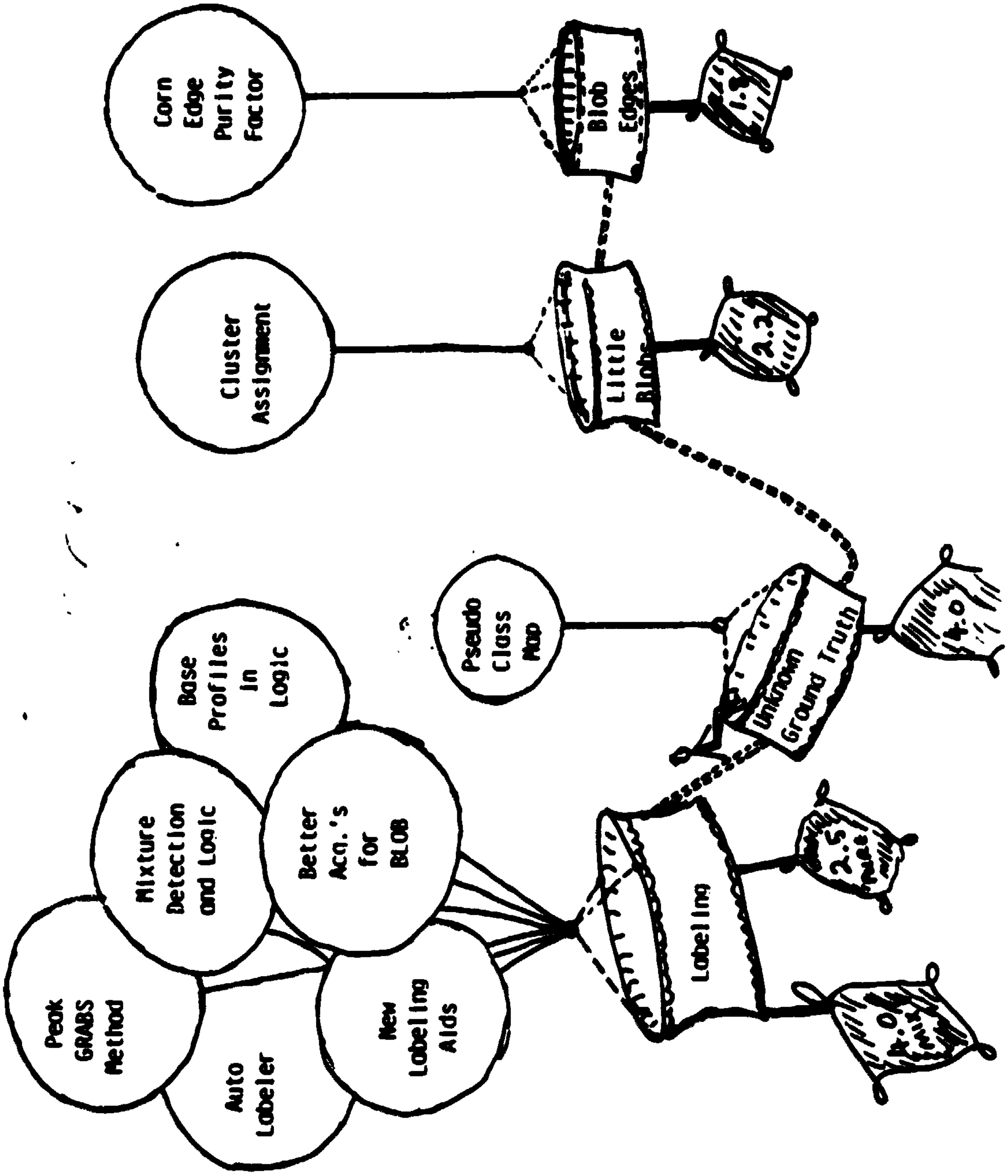
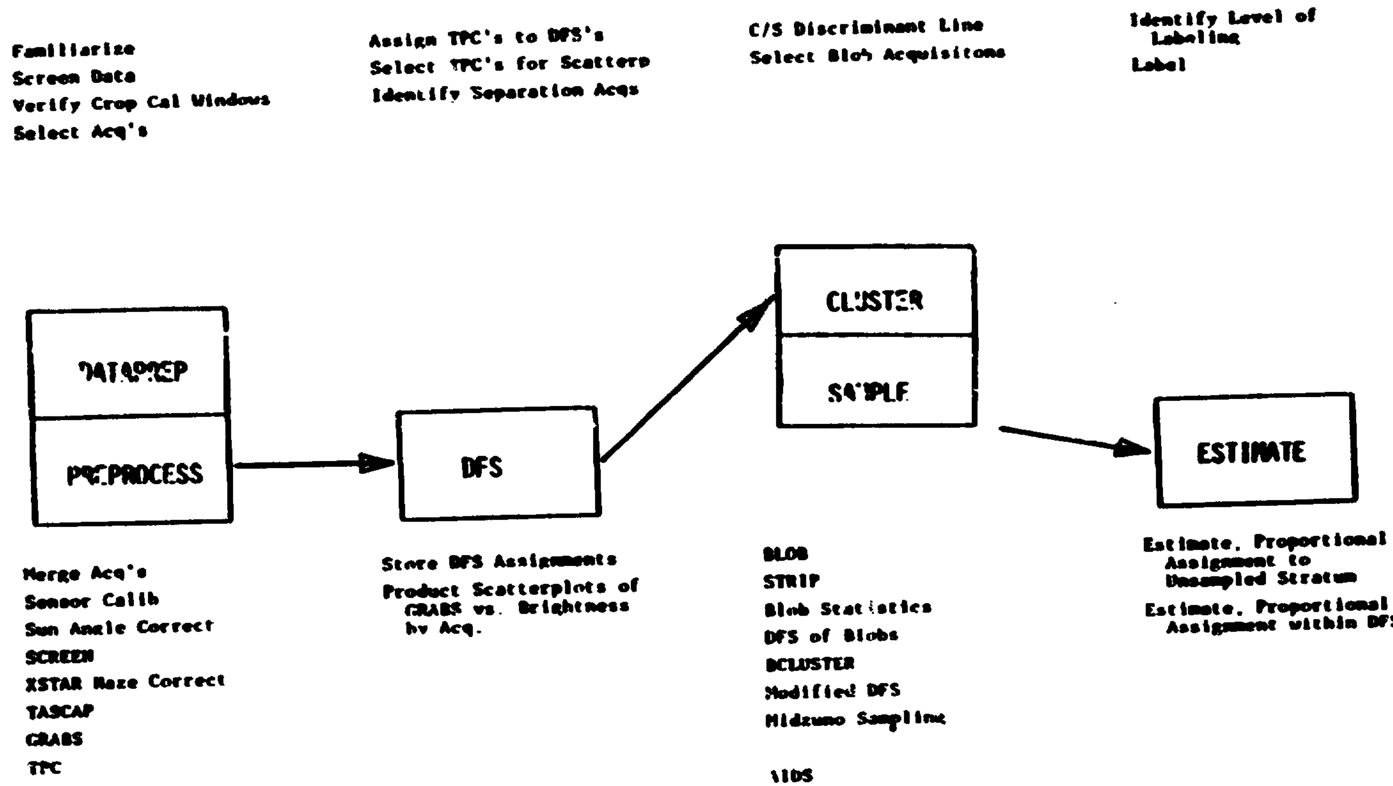


CURRENT BASELINE PROCEDURE



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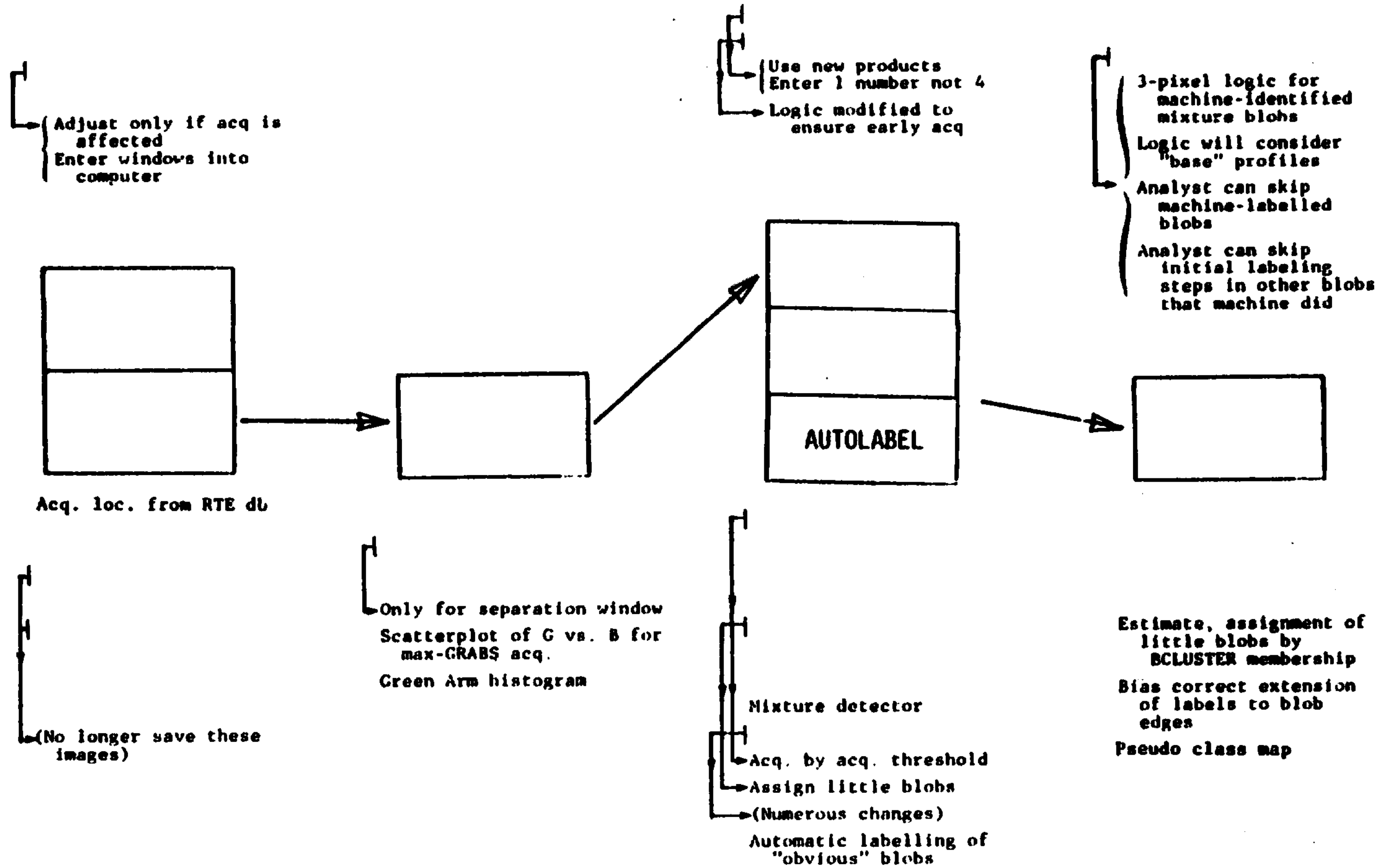
CHANGES TO


Adjust only if acq is affected
Enter windows into computer
Acq. loc. from RTE db
(No longer save these images)
Only for separation window
Scatterplot of G vs. B for max-GRABS acq.
Green Arm histogram
Use new products
Enter 1 number not 4
Logic modified to ensure early acq
AUTOLABEL
Mixture detector
Acq. by acq. threshold
Assign little blobs
(Numerous changes)
Automatic labelling of "obvious" blobs
3-pixel logic for machine-identified mixture blobs
Logic will consider "base" profiles
Analyst can skip machine-labelled blobs
Analyst can skip initial labeling steps in other blobs that machine did
Estimate, assignment of little blobs by BCLUSTER membership
Bias correct extension of labels to blob edges
Pseudo class map

ANALYST

Familiarize

Screen Data

Verify Crop Cal Windows

Select Acq's

Adjust only if acq is affected

Enter windows into computer

DATAPREP

PREPROCESS

→ DFS

MACHINE

Merge Acq's

Sensor Calib

Sun Angle Correct

SCREEN

XSTAR Haze Correct

TASCAP

GRABS

TPC

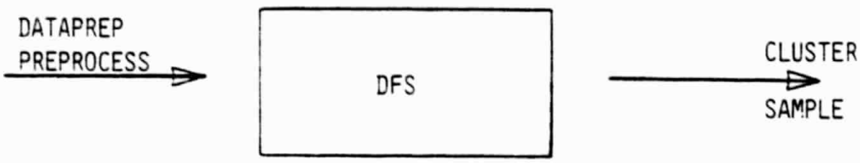
(No longer save these images)

ANALYST

Assign TPC's to DFS's

Select TPC's for Scatterp

Identify Separation Acqs



Store DFS Assignments

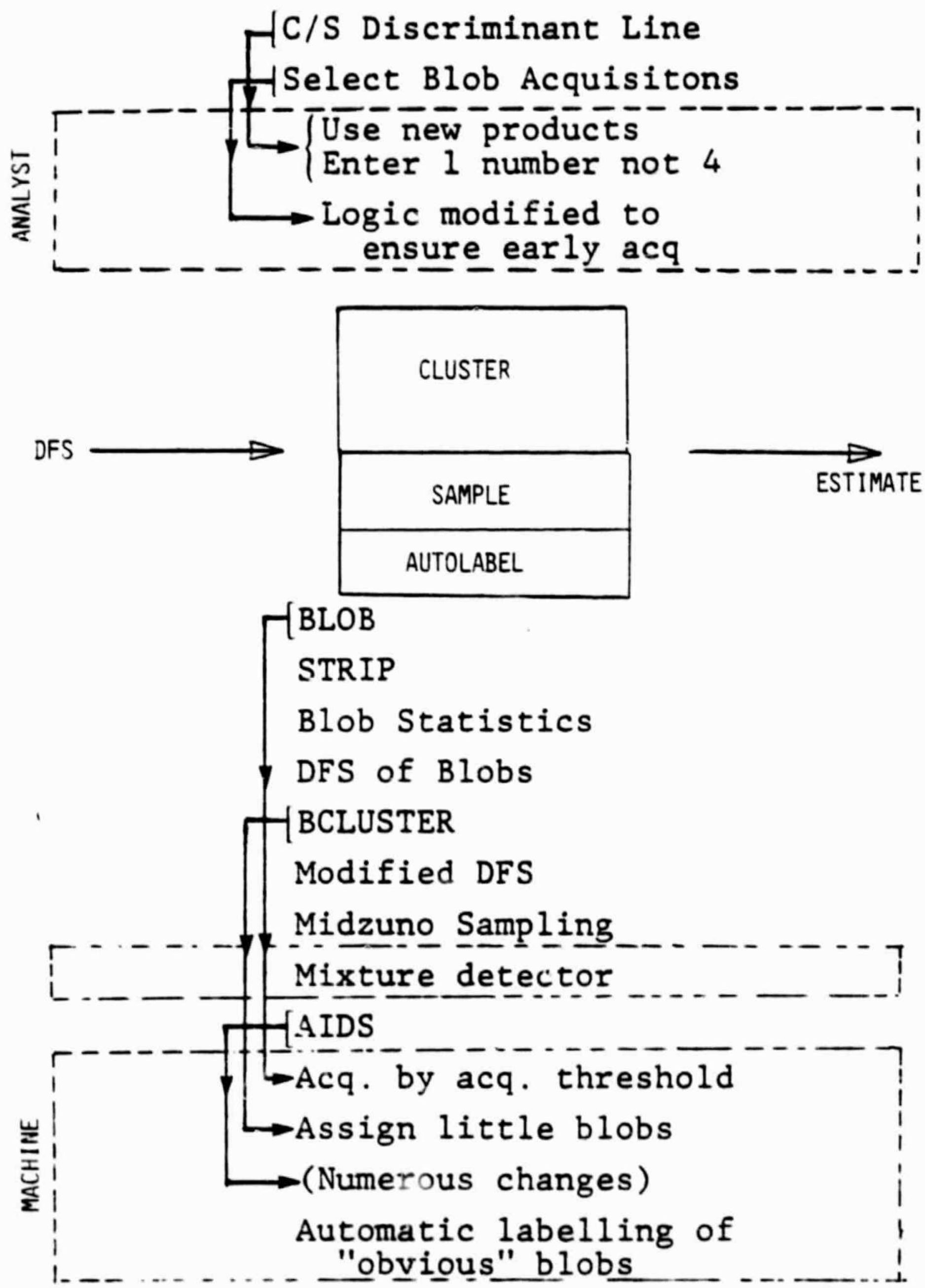
Product Scatterplots of GRABS vs. Brightness by Acq.

MACHINE

Only for separation window

Scatterplot of G vs. B for max-GRABS acq.

Green Arm histogram


C/S Discriminant Line
Select Blob Acquisitons
ANALYST
Use new products
Enter 1 number not 4
Logic modified to ensure early acq
CLUSTER
DFS
SAMPLE
ESTIMATE
AUTOLABEL
BLOB
STRIP
Blob Statistics
DFS of Blobs
BCLUSTER
Modified DFS
Midzuno Sampling
Mixture detector
AIDS
MACHINE
Acq. by acq. threshold
Assign little blobs
(Numerous changes)
Automatic labelling of "obvious" blobs

Identify Level of Labeling

Label

ANALYST

- 3-pixel logic for machine-identified mixture blobs
- Logic will consider "base" profiles
- Analyst can skip machine-labelled blobs
- Analyst can skip initial labeling steps in other blobs that machine did

SAMPLE CLUSTER → ESTIMATE

- Estimate, Proportional Assignment to Unsampled Stratum
- Estimate, Proportional Assignment within DFS

MACHINE

- Estimate, assignment of little blobs by BCLUSTER membership
- Bias correct extension of labels to blob edges

LIST OF CHANGES (1)

<u>Aimed Principally at Information Gathering</u>

- Accuracy assessment software
- Pseudo class map

<u>Aimed Principally at Efficiency</u>

- Acquisition locations automatically retrieved from RT&E data base
- Reduced image storage
- Scatterplots for separation acq's only
- Auto labeling for easy targets also appears below

(continued)

LIST OF CHANGES (2)

<u>Aimed Principally at Error (Bias) Reduction</u>

1. Crop calendar adjustment logic

2. C/S separation line

   - Green arm histogram
   - Maximum GRABS scatterplot
   - Discriminant placement logic

3. Blob acquisition selection logic

4. Blob decision rule modification

5. Little blob and big clustering (unsampled stratum correction)

   - "Classification" to Bclusters
   - Estimation logic change

LIST OF CHANGES (2) (continued)

6. Correction for big blob edge

7. Mixtures handling

   - Auto detection of probable mixtures
   - 3-pixel mixture labeling logic

8. Changes in labeling

   - Revised analyst aid package
   - Auto labeling of easy targets
   - Incorporation of standard profiles into logic

1. CROP CALENDAR ADJUSTMENT LOGIC

<u>Change</u>

- Crop calendar windows will not be modified unless an acquisition will be affected
- The machine will receive the crop calendar window definitions

<u>Effect</u>

- Minor change aimed at improving analyst consistency
- Assists auto-labeler
- Sets up for future automation of DFS

2. CORN/SOYBEAN LINEAR DISCRIMINANT

<u>Change</u>

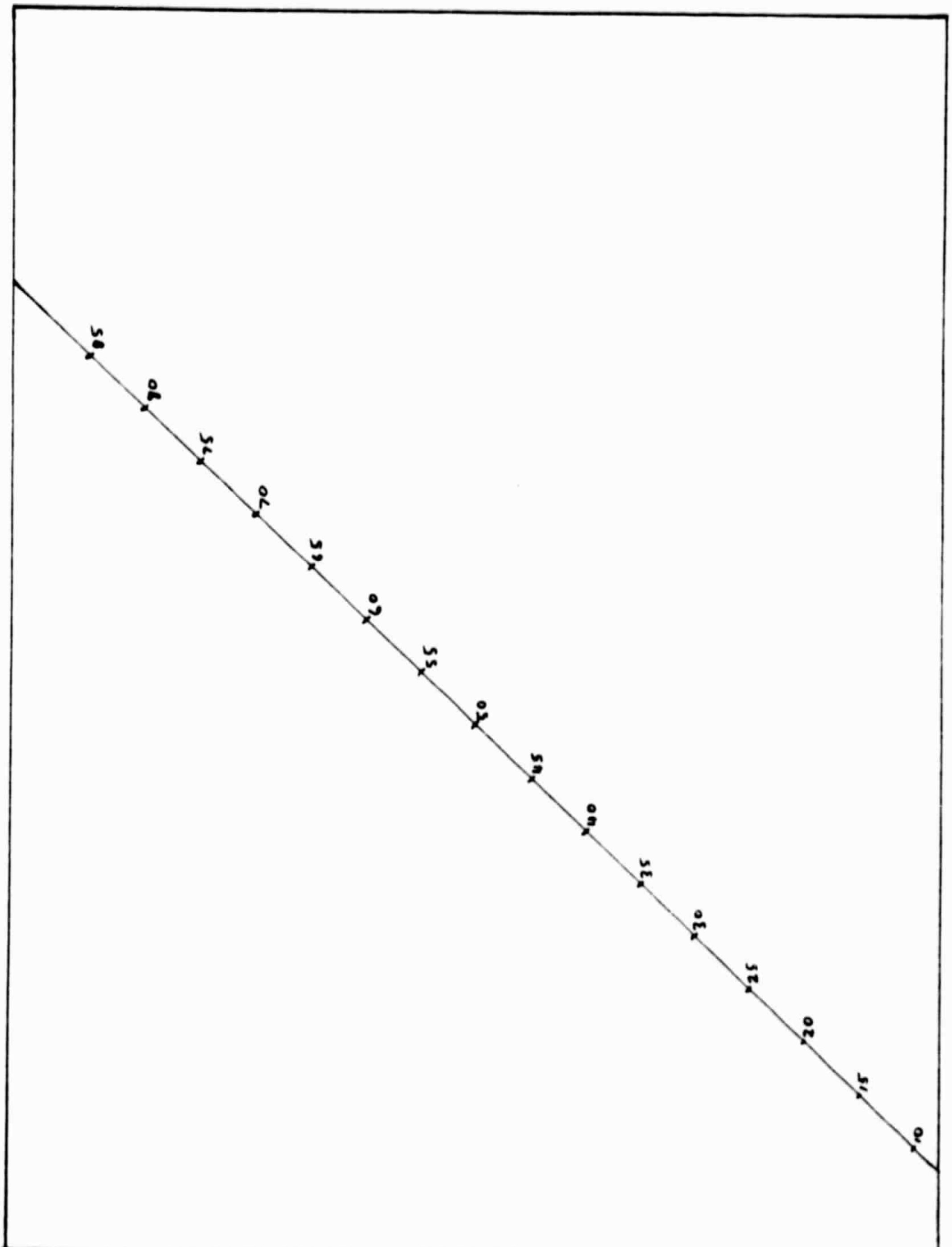
- Scatterplot of GRABS vs. Brightness, using pixels from acquisition of maximum GRABS, will be produced
- A histogram representing projection of that scatterplot onto Tasseled-Cap "Green Arm" will be produced
- Discriminant boundary will be histogram coordinate instead of two (x,y) points

<u>Significance</u>

Example GRABS vs. BRIGHTNESS

a Max GRABS

Scatterplot



Example

Green Arm Histogram

3. BLOB ACQUISITION SELECTION LOGIC

Change

- The analyst will be more effectively guided in selecting pre-season and separation acquisitions for blob

Effect

- A significant reduction in mixture blobs (factor of 2) is expected
- An improvement in blob purity will result (88.3% instead of 83.4%)

4. BLOB DECISION RULE

<u>Change</u>

- Previous spectral rule: assigns pixel to same blob if:

$$\sum_{\text{all channels}} \frac{(X_i - \mu_i)^2}{\text{var}_i} < \tau$$

- New spectral rule:

$$\sum_{\text{all channels}} \frac{(X_i - \mu_i)^2}{\text{var}_i} < \tau_{\text{general}} \ \underline{\text{and}} \ \sum_{\text{preseason}} \frac{(X_i - \mu_i)^2}{\text{var}_i} < \tau_{\text{preseason}}$$

and

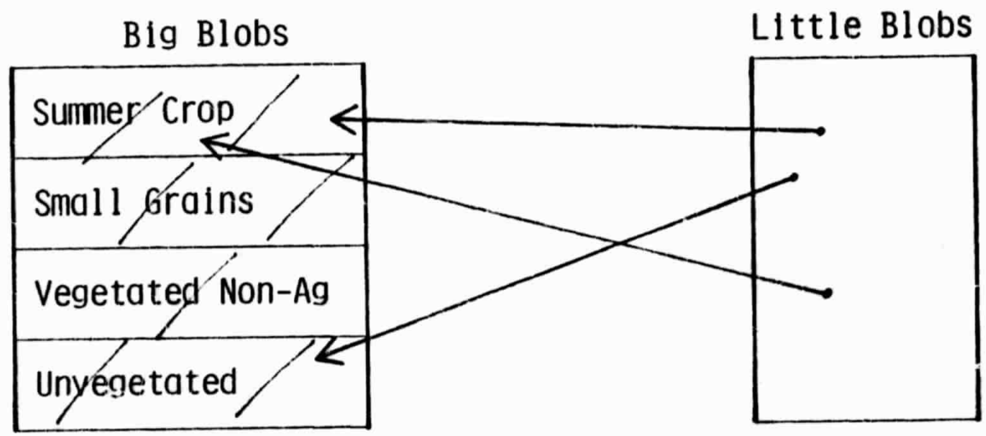
$$\sum_{\text{separation}} \frac{(X_i - \mu_i)^2}{\text{var}_i} < \tau_{\text{separation}}$$

<u>Effect</u>

- No change in corn blob purity
- Modest (1%) change in overall blob purity

5. LITTLE BLOB CLUSTERING; UNSAMPLED STRATUM CORRECTION

Change



- Assign little blobs to crop group stratum
- Spectrally assign little blobs to specific clusters within crop group stratum ('Classify' the little blobs into clusters)
- Use spectral cluster associations to extend labels

Effect

- Error reduced by factor of 2

6. CORRECTION FOR BIG BLOB EDGE

<u>Change</u>

- We noted that big blob edges tended to be less pure than big blob interiors
- We noted that <u>corn</u> blob edges were very consistently 10% less pure than <u>soy</u> or <u>other</u> blob edges
- Hence assign 10% of <u>corn</u> blob edge area to <u>soy</u> and <u>other</u> in proportion to relative abundance of soy and other (corn edge purity factor)

<u>Effect</u>

- Extension of label from blob interior to blob edge is nearly unbiased in one test
- 30% improvement in the error due to this source

	Baseline		With Unsampled Stratum Correction		With Edge Impurity Correction Modification W/o Edge Bias	
	Error	Std.Dev.	Error	Std. Dev.	Error	Std.Dev.
Corn	2.52	1.59	1.40	1.25	0.44	
Soy	-2.86	2.35	-0.65	0.95	-0.53	
Other	0.34	2.03	-0.75	1.47	0.99	
RMS	3.8		1.7		1.2	

7.1 MIXTURES -- DETECTION

<u>Change</u>

- If blob is in zone A,
- And average GRABS standard deviation in windows SC1, SC3, SC5 is less than 2.9
- Then blob is flagged as "probably mixed"

<u>Effect</u>

- About 55% of the mixture blobs are correctly flagged (rule of 80% purity)
- About 15% of the pure blobs are falsely flagged
- There is much segment-segment variation in performance

7.2 MIXTURES -- REVISED LABELING LOGIC

<u>Change</u>

- Machine identifies probable mixture blobs (7.1)
- Machine randomly selects 3 pixels from each such blob
- Machine generates aids separately for each pixel
- Analyst labels each of the 3 pixels

<u>Effect</u>

- Pixel method reduces mixing of signals
- Pixel selection is unbiased sample
- Analyst will still have some mixture pixels to label, but overall effect should be improvement of biggest source of error

8.1 CHANGES IN LABELING - AID PACKAGE

<u>Changes</u>

- List of blobs is divided into two parts -- auto-labeled, and not so
- List of blobs and subsequent aids sorted into:
  - auto labeled (by crop type and number of interiors)
  - not-mixed (randomized)
  - mixed (randomized)
- Delete any reference to DFS
- Add the following for auto-labeled blobs
  - label
  - distance from C/S discriminant
  - zone
  - decision logic path
  - enclosing rectangle
- Compact version of G vs. T plots for auto-labeled blobs

8.1 CHANGES IN LABELING - AID PACKAGE (continued)

- Delete GRABS vs. Brightness plots (not used)
- Special pixel-level aids (particularly G vs. T plots), in addition to standard ones, for mixture blobs

Effect

- Most changes mechanically required by 7, 8.2
- Errors due to analyst using DFS too strongly should be eliminated (if DFS ≠ summer-crop, then analyst rarely detects soybeans or corn)
- Other effects not fully known

8.2 CHANGES IN LABLEING - AUTOMATIC LABELING OF EASY TARGETS

Change

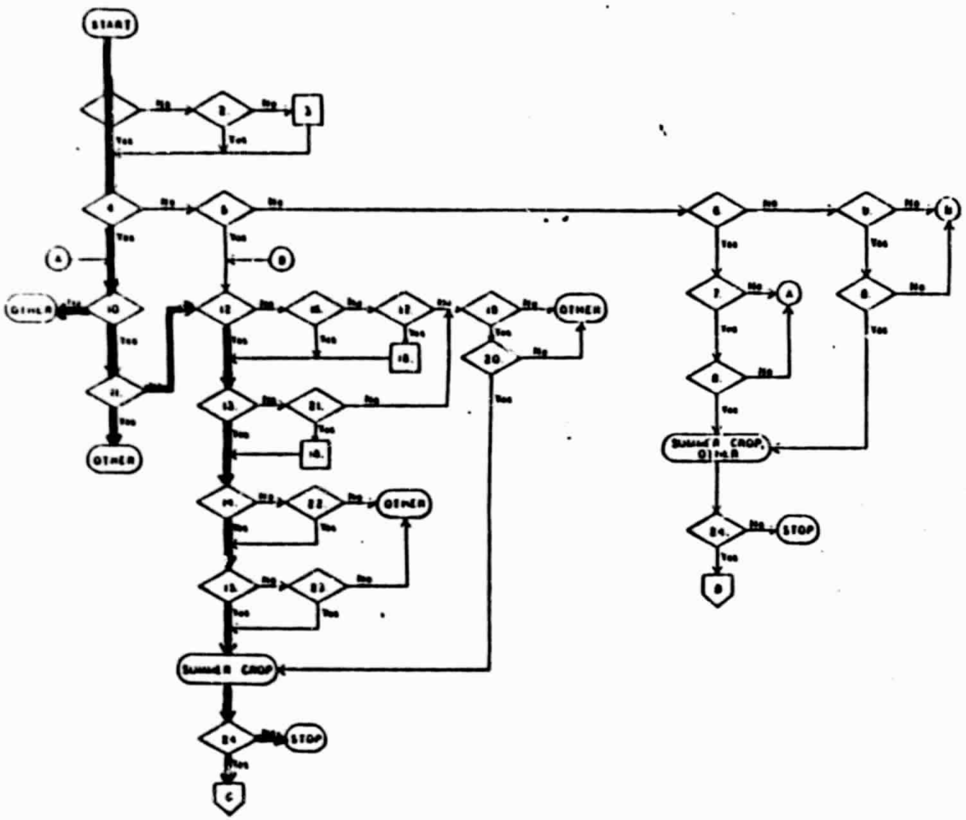
- Machine labels "classic" targets
- Machine indicates to analyst where target is "non-classic"
- "Classic" profiles are presented to analyst

Effect

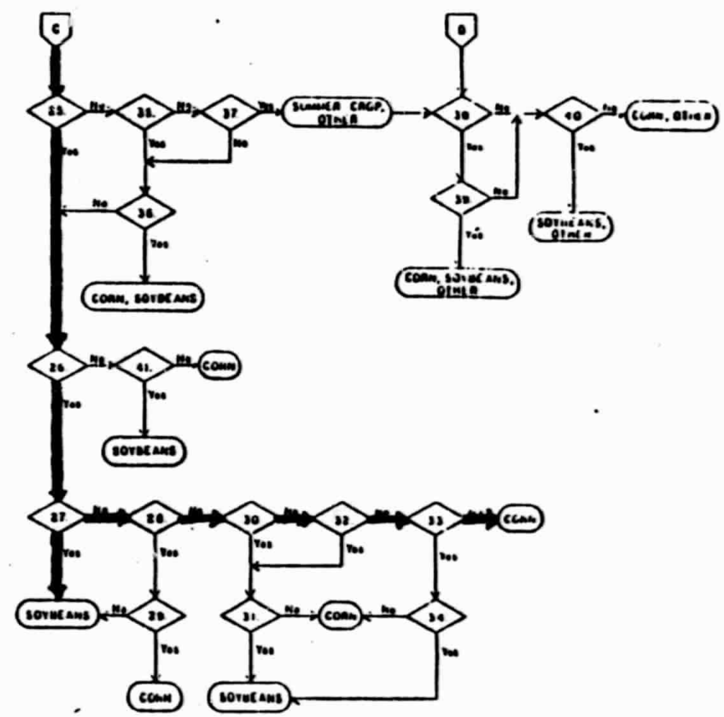
- Improved consistency in objective decision logic path
- Decreased analyst effort required at labeling stage, allowing analyst to concentrate on targets which require analysis
- Expect 30-40% of blobs will be auto-labeled

DECISION LOGIC PATHS ALLOWED FOR AUTOMATIC LABELER

Crop Group Decision Logic



Crop Type Decision Logic



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LABELING PERFORMANCE OF AUTOMATIC LABELER

		Ground Truth		
		Corn	Soy	Other
Auto Labeler	Corn	130	3	1
	Soy	3	164	3
	Other	0	0	35

8.3 CHANGES IN LABELING -- INCORPORATION OF STANDARD PROFILES

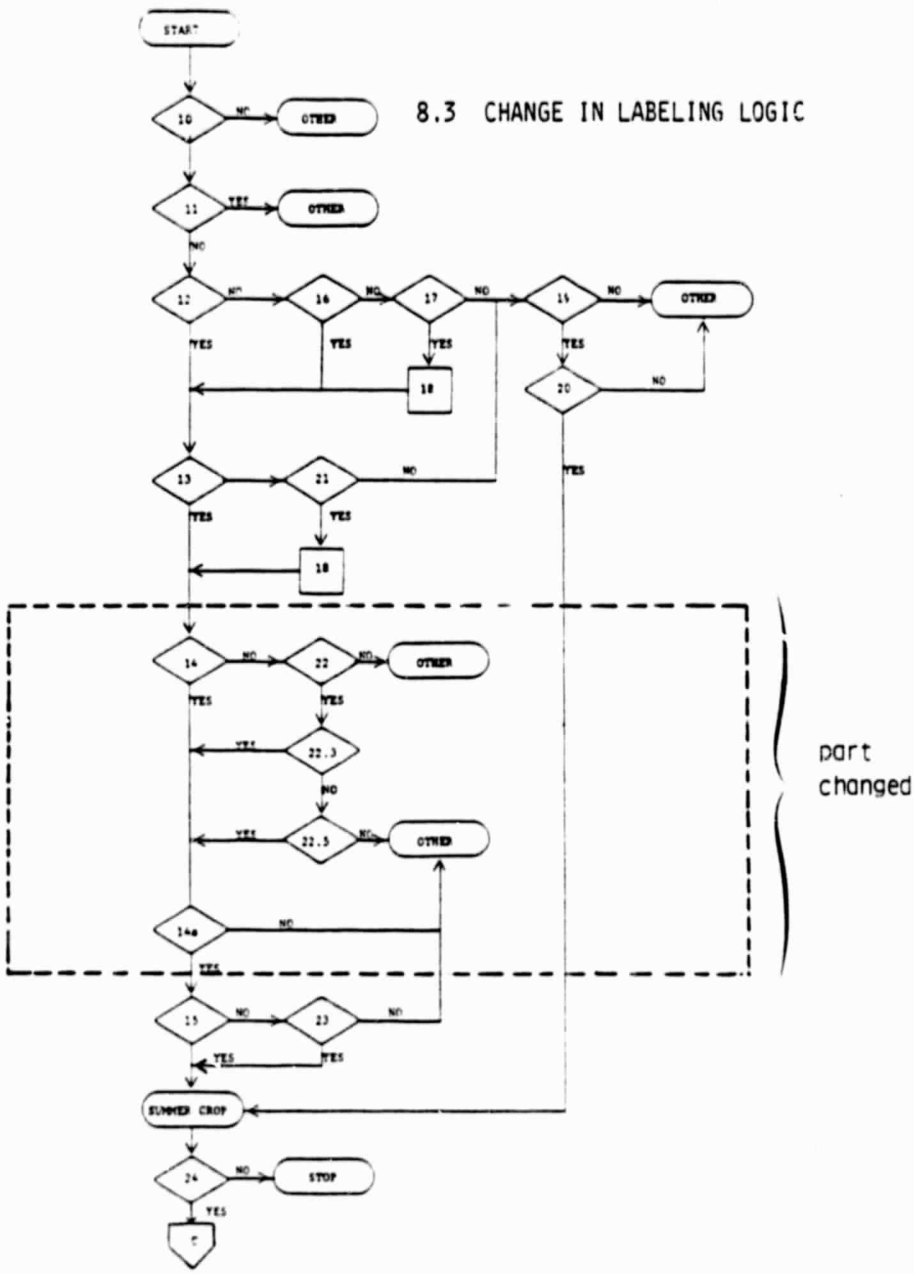
Change

- We noted that up to 50% of pure blob analyst labeling error is related to double-peaked GRABS vs. Time profiles
- Analyst logic (questions 14 and 22), that considers variant summer crop signatures, was revamped
- This modification provides 14 reference profiles, including double-peaked ones

Effect

- This is targeted at fixing half the pure blob labeling error

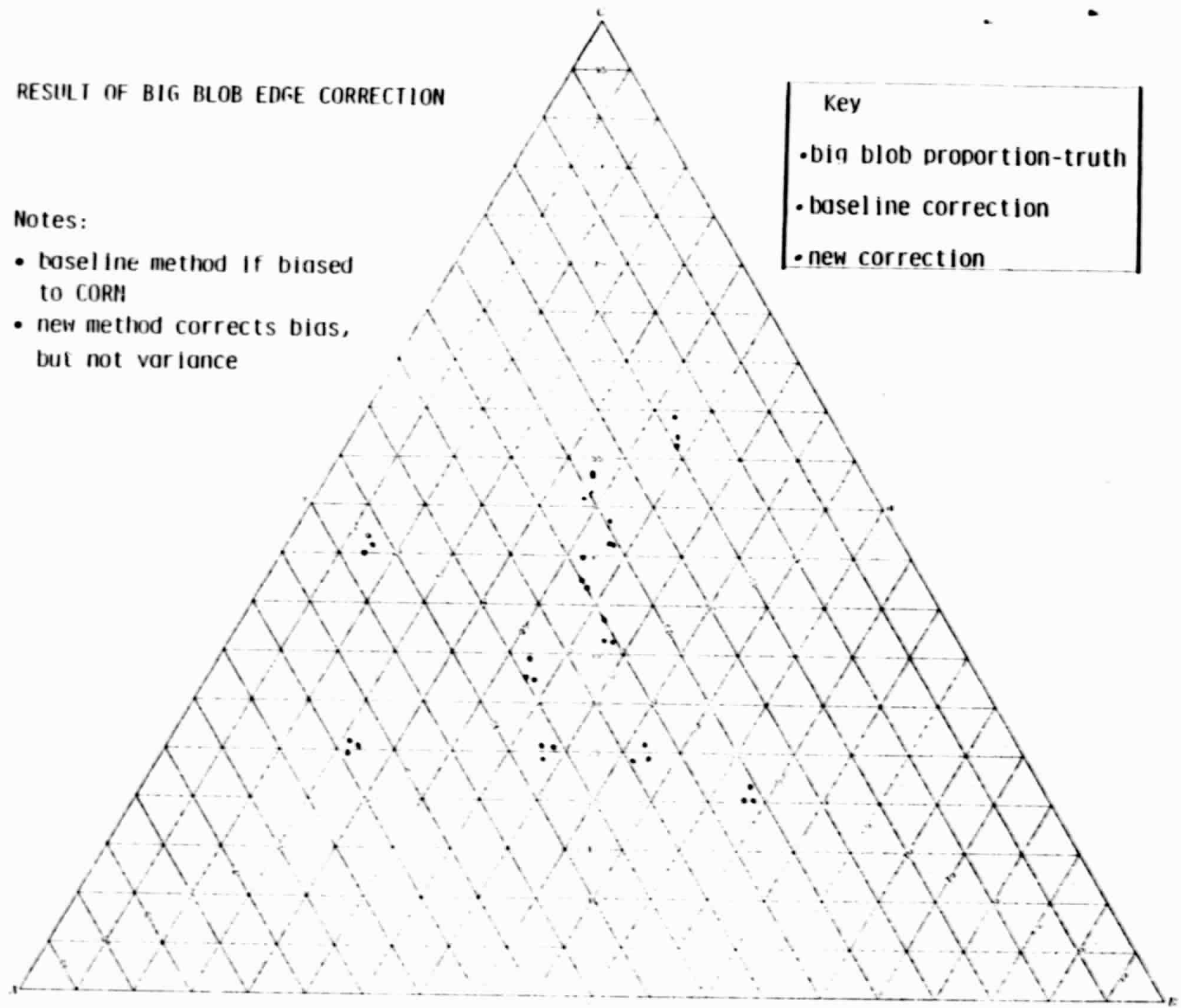
8.3 CHANGE IN LABELING LOGIC



RESULT OF BIG BLOB EDGE CORRECTION

Notes:

- baseline method if biased to CORN
- new method corrects bias, but not variance



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COMMENTS ON EXPECTED RESULTS OF OVERALL CHANGES

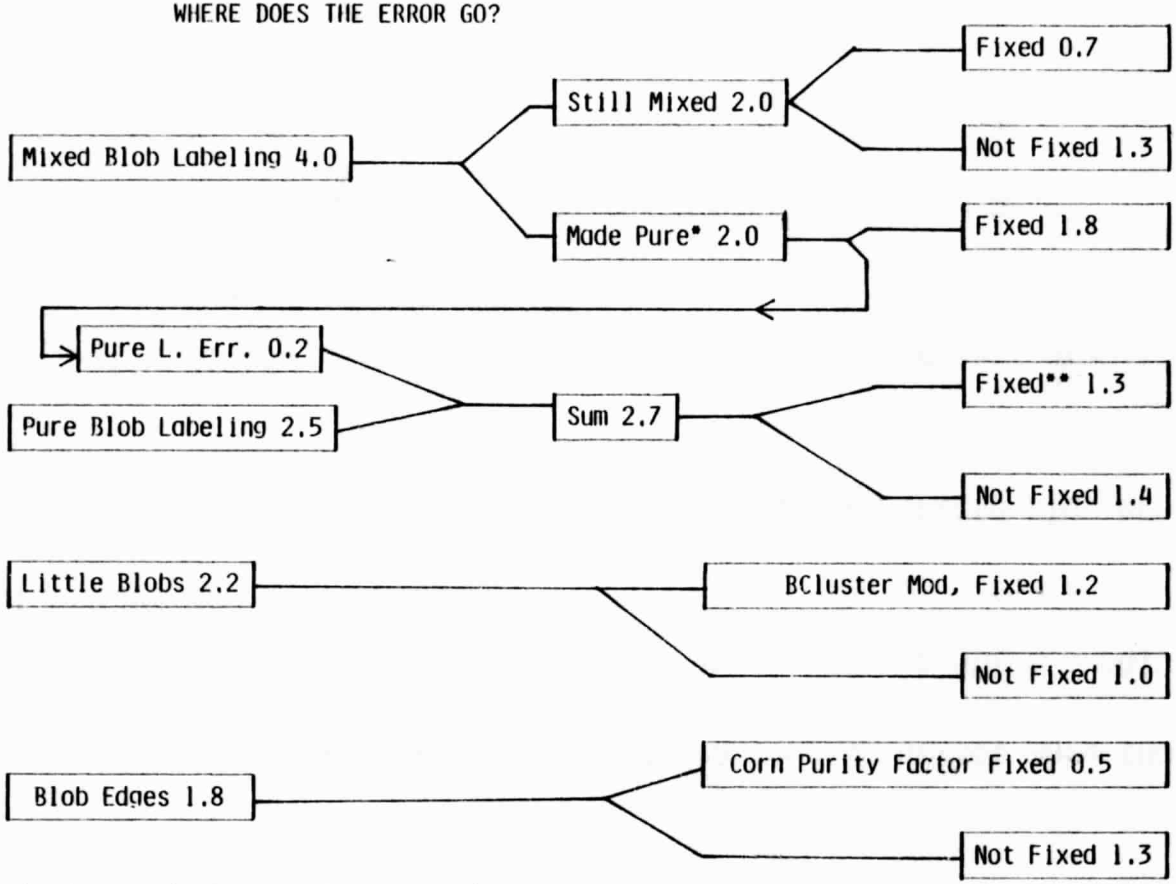
- Study not complete on some mods; researchers' opinions used
- Combined effect of changes has not been addressed

C-3

BOTTOM LINE FEELING

Percent of Error Fixed	52%
Percent Not Fixed	48%
	100%

WHERE DOES THE ERROR GO?



*made pure by better blob acq. select, etc.
*fixed by logic mods, better aids, auto labeling

WHAT SHOULD BE DONE IN ADVANCE OF UPCOMING TEST

- Effect of analyst logic changes should be tested (especially mixtures) and perhaps tuned
- Mixture detection procedure should be improved (can we detect more than half?)
- Greater technical understanding of the blob edge purity problem should be sought (is new method robust?)
- Study of field size distributions, and relationship to little blob problem, should occur
- Nature of bad (unknown) ground truth problem should be investigated (is A.A. ground truth encoding scheme biased?)
- Some measure of integrated effects of all changes should be made

LONG RANGE ACTIVITIES

- Automation and objectifying of most of procedure
- Improvement of existing technologies
  - BLOBbing
  - field size distribution information
  - preprocessing
- Consideration of alternative technologies
  - dot-oriented approaches
  -
  -
- Adapting the procedure to Argentina environment
  - validate preprocessing techniques
  - incorporate new confusion crop procedures
  -
  -

CORN AND SOYBEAN SEPARABILITY

ERIM/UCB FCPF C/S Consortium

Technical Note

Presented at

FCPF Quarterly Technical Interchange

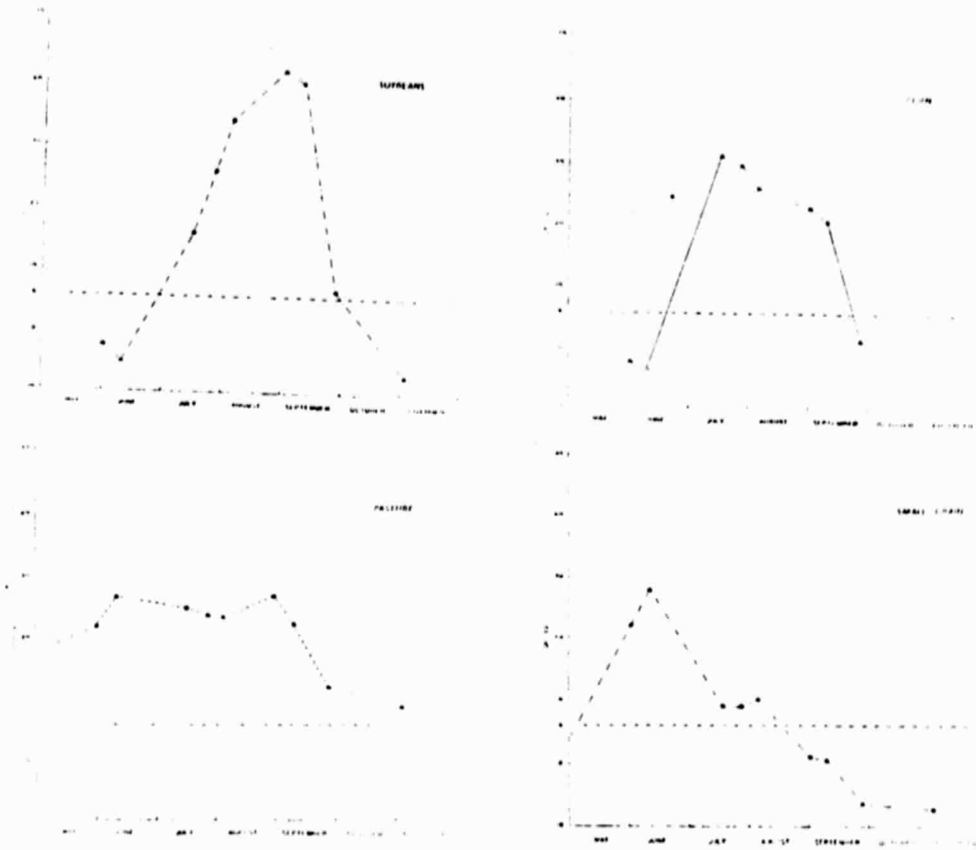
July 1981

TECHNICAL ISSUE

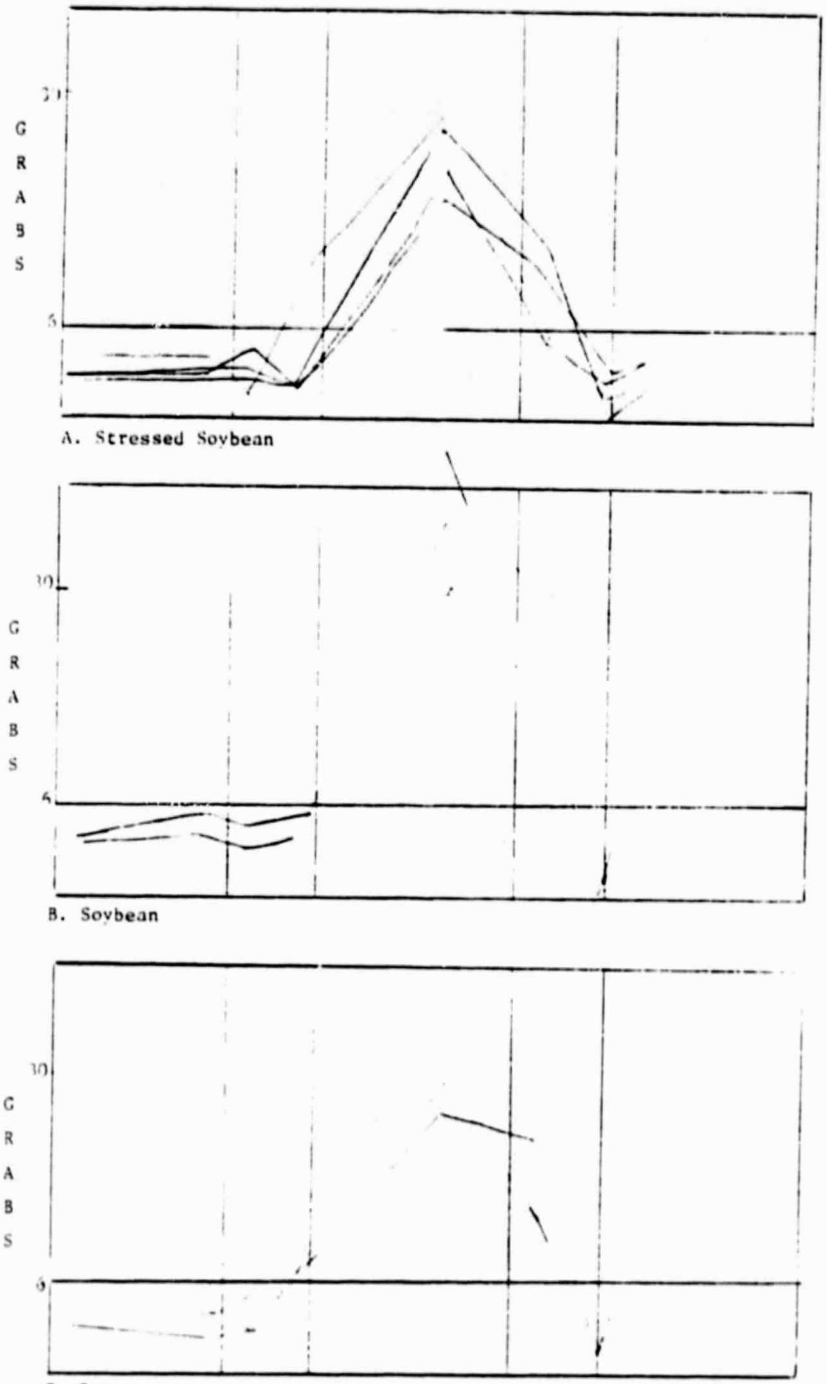
- Fundamental Limitations are Observed in Separating Corn and Soybeans Based on Existing Guidelines for Discriminantion

- Misregistration, Sensor Resolution or Stressed Conditions May Affect Soy Pixels Such that They are Neither Represented by 'Super Pures' Nor Separable from Corn and Other Classes

C/S LABELING GUIDELINES



SEPARABILITY OF CORN AND SOY UNDER CONDITIONS OF STRESS

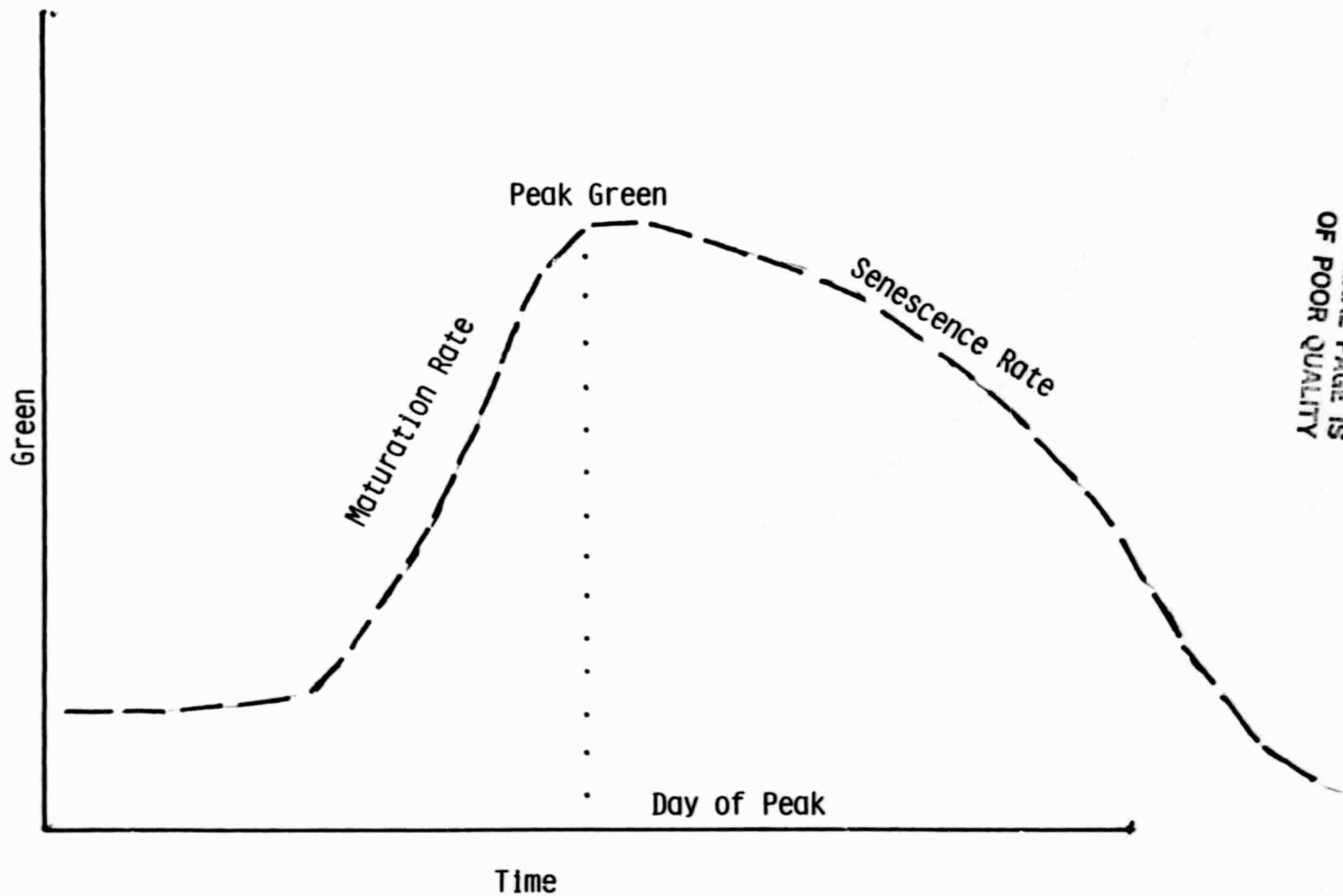


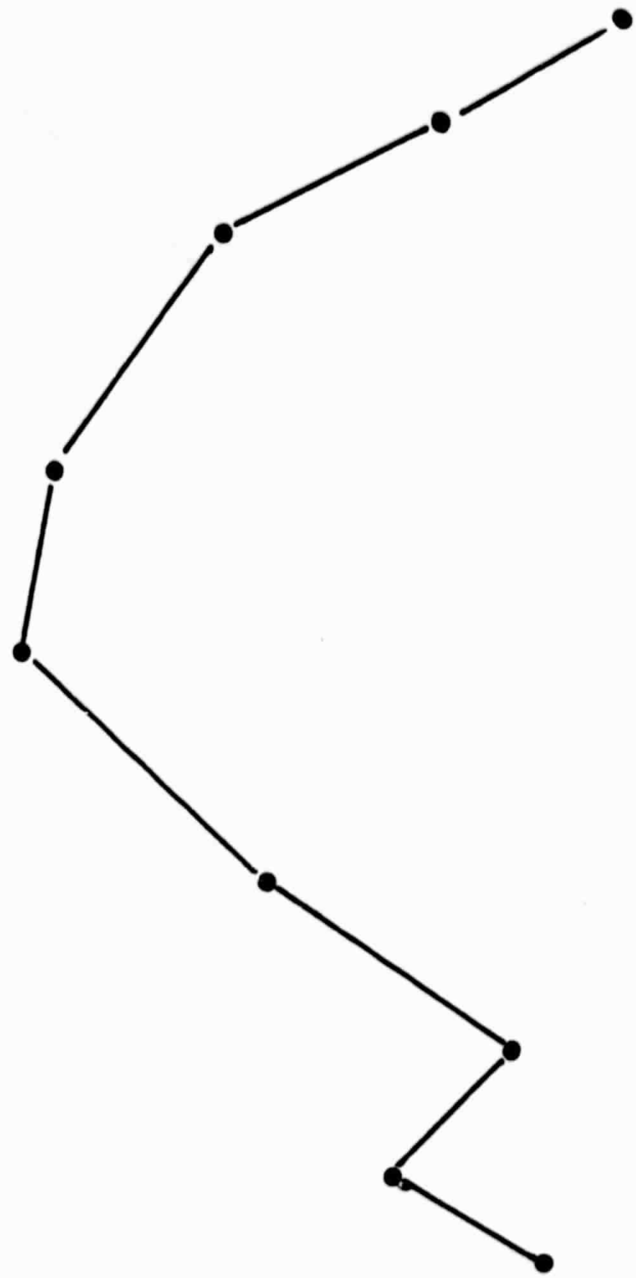
A. Stressed Soybean

B. Soybean

C. Corn

DETERMINATION OF PROFILE FEATURES





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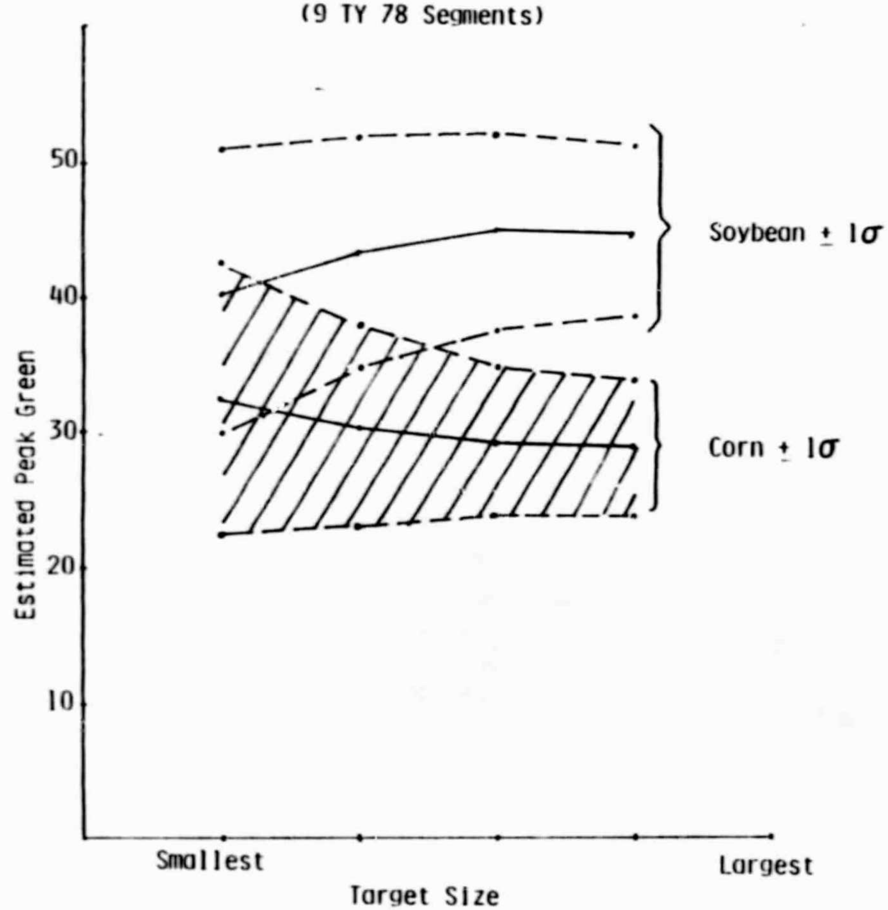
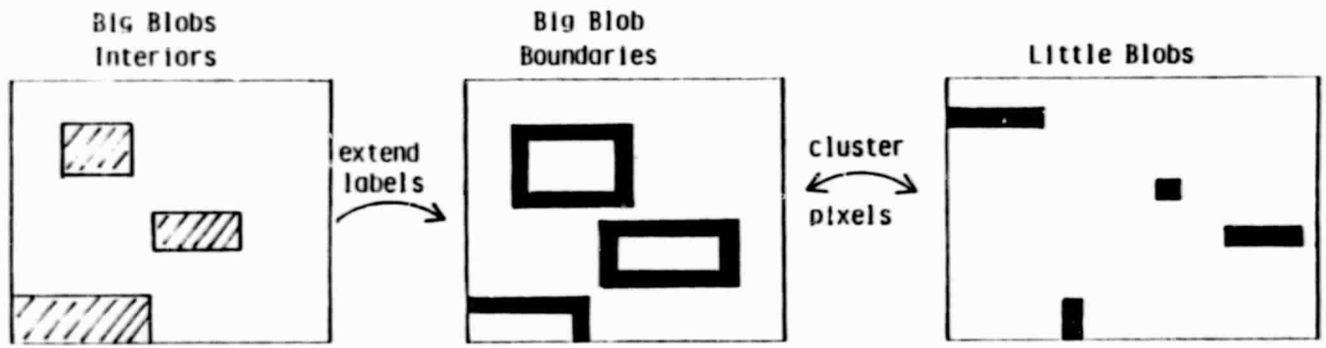
CROP SEPARABILITY AS A FUNCTION OF TARGET SIZE

(9 TY 78 Segments)



MODIFICATION #2 TO BASELINE CORRECTION FOR

UNSAMPLED STRATUM*



1. Sample, label and produce an S.A.E. for big blob interiors
2. Extend interior label to boundary
3. Cluster big blob boundary pixels
4. Assign little blob pixels to clusters formed in 3, thereby 'classifying' little blobs
5. Produce a composite estimate (weighted average of 1 and 4)

*This modification has not been implemented, but is being researched.

MODIFICATION #2 PERFORMANCE AS A FUNCTION OF
DEFINTION OF LITTLE BLOBS

Error

	Definition of Little Blobs			
	<1 Pixels	<2 Pixels	<3 Pixels	<4 Pixels
Corn	0.45	0.95	1.37	1.77
Soy	-0.90	-1.01	-1.19	-1.37
Other	0.45	.06	-0.18	-0.40

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HYPOTHETICAL EXPLANATION

- Smaller Blobs are Dominated by Soy and Other Due to Field Size Distributions

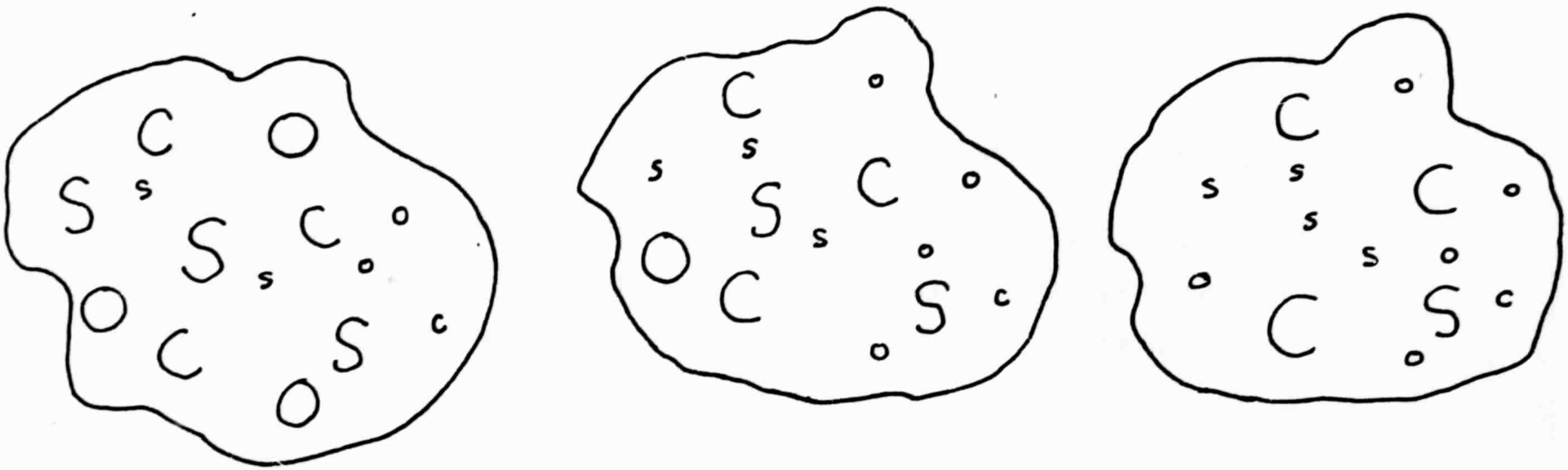
- Spectral Appearance of Soy, Corn, and Other Among Smaller Blobs is Less Unique Causing Mixed Clusters to Form

- As Additional Blobs are Omitted from the Training Set, Corn will Tend to Dominate the Training Set Causing a Bias in its Favor

ILLUSTRATION OF HYPOTHESIS

Definition of Little Blobs

TRUE	<1 Pixel	<2 Pixels	<3 Pixels



TRUE	Estimate	Estimate	Estimate
C 2/7	1/3	1/2	3/4
S 5/14	1/3	1/3	1/4
O 5/14	1/3	1/6	0

SUMMARY

- Corn and Soybean Classes are Less Separable in the Presence of Stressed Conditions
- Segments Affected by Misregistration or that are Dominated by Small Fields Will Likely Exhibit Less Spectral Separability
- Additional Research to Verify the Existence of this Fundamental Spectral Limitation in Discrimination of Corn and Soybeans and to Quantify its Affect on Segment Acreage Estimation is Required
- Techniques that are Robust in the Presence of these Conditions are Needed

STATUS SUMMARY OF SOFTWARE TECHNOLOGY

ERIM/UCB FCPF
CORN AND SOYBEAN CONSORTIUM
O. MYKOLENKO - TASK LEADER

PRESENTED AT

FCPF QUARTERLY TECHNICAL INTERCHANGE

JULY 1981

OUTLINE

- Review of Existing Capability
- Recent Activity
- Ongoing Activity
- Future Plans

S T A R S

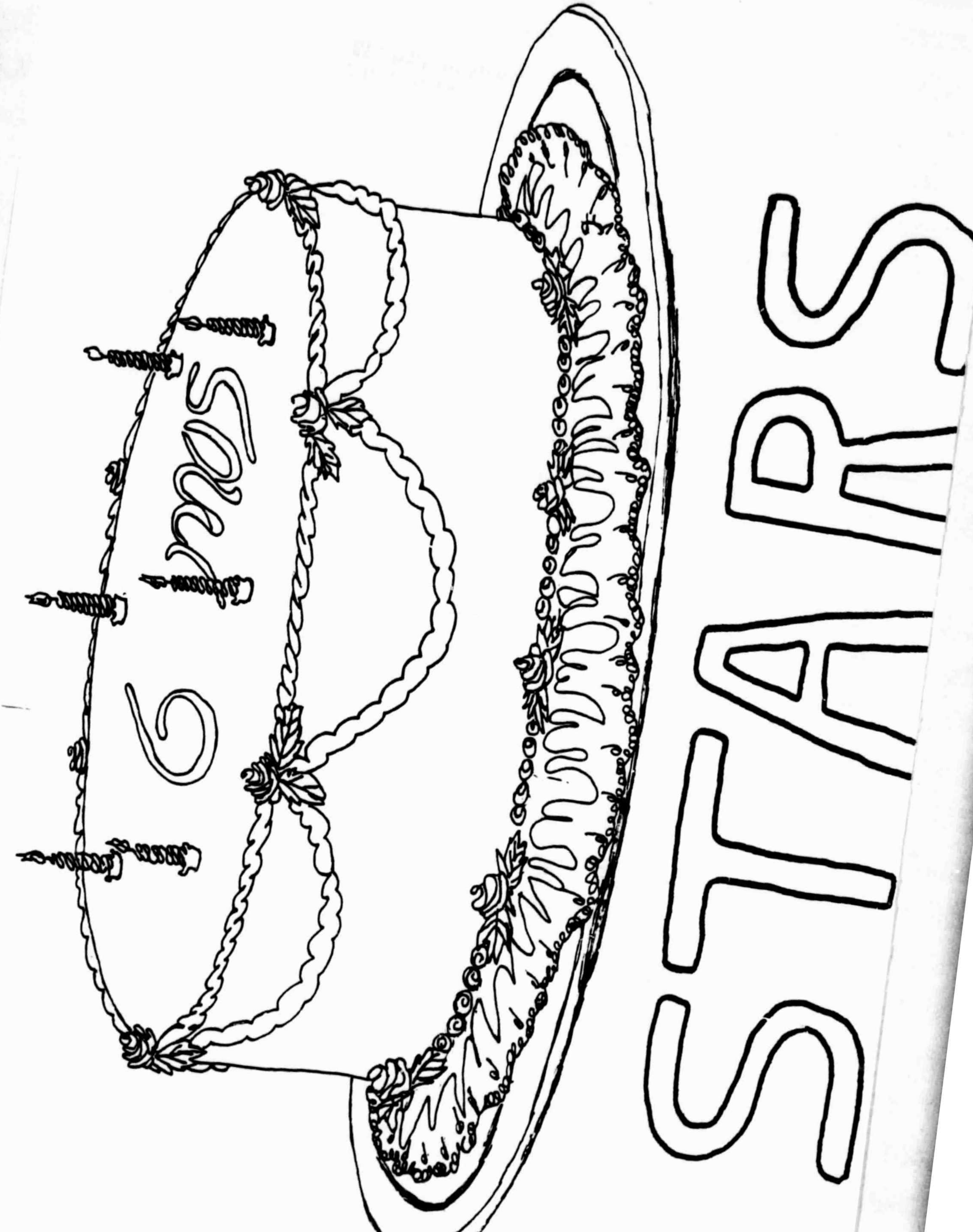
SOFTWARE

TECHNOLOGY FOR

AEROSPACE

REMOTE

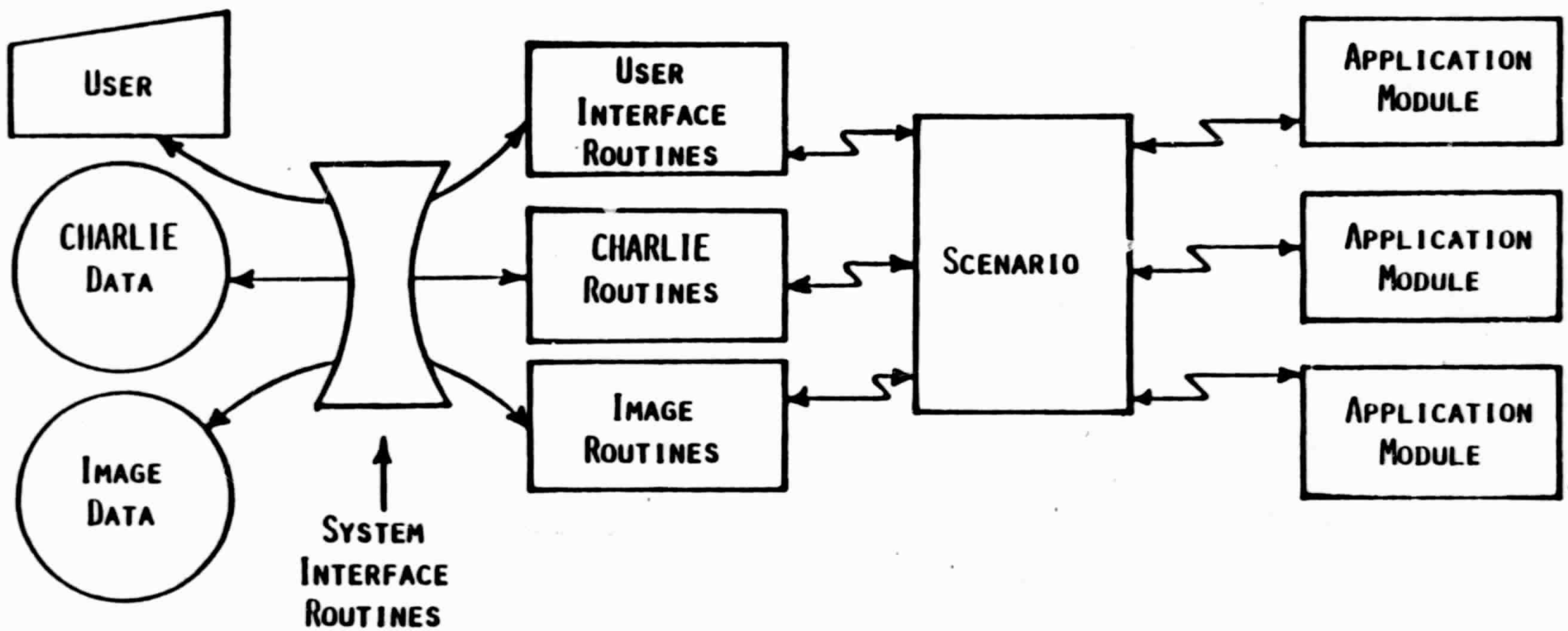
SENSING


STARS

KEY DESIGN ELEMENTS

- Simple High Level User Interface
- Status and Tracking
- Efficient Single Function Application Modules
- Data Management Services
- Operating System Independence

SYSTEM ORGANIZATION



ERIM

APPLICATIONS

- Available on 3 computers and 2 different operating systems
- US C/S Baseline Procedure

DATAPREP	ASK	DFS
PREPROCESS	CLEAR	SCATTER
CLUSTER	SAMPLE	ESTIMATE
TAPEDISK	DISKTAPE	TRANSMIT
USERINIT	TAPELOG	

- Recent research oriented capabilites

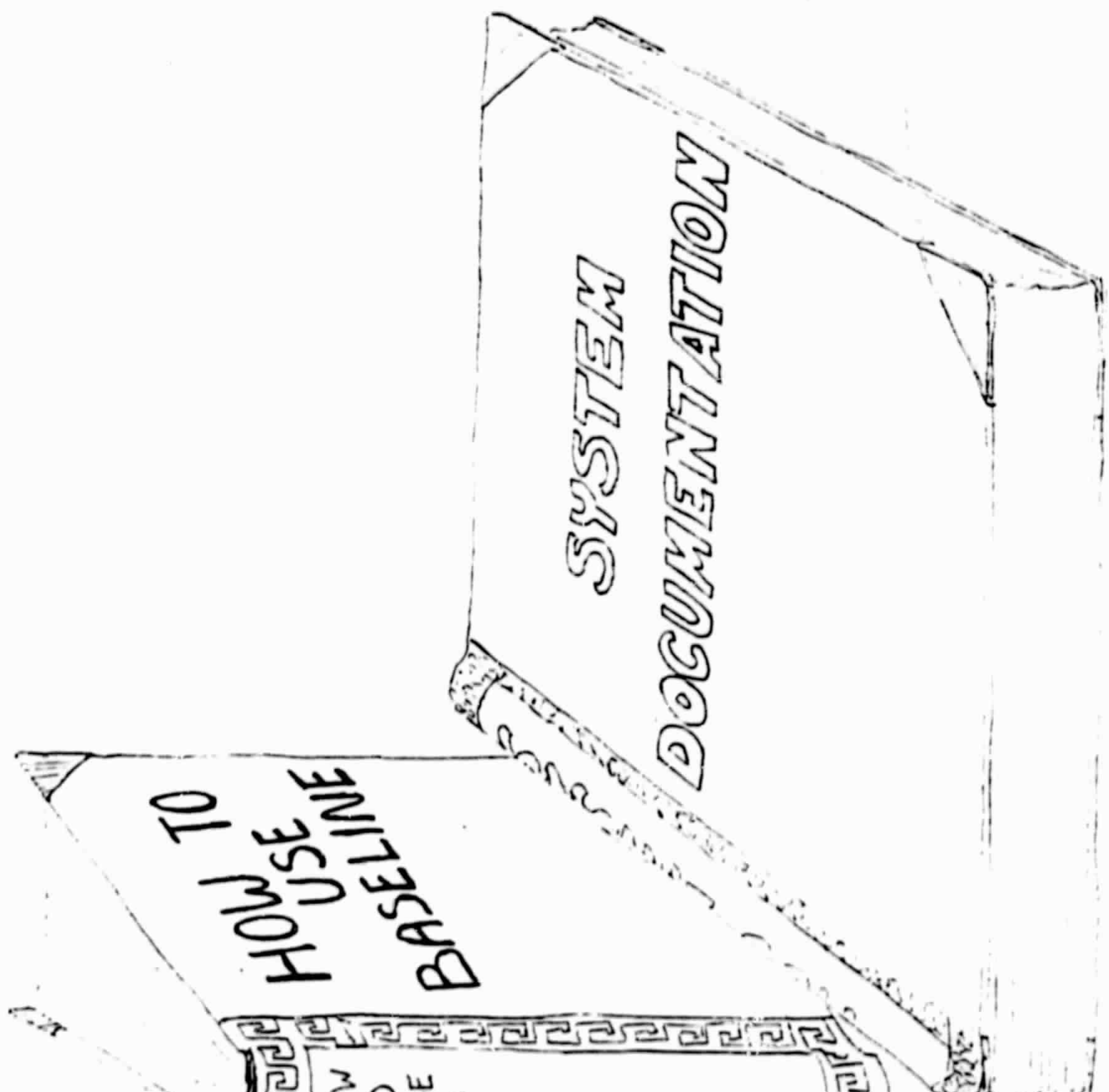
BLOBSTAT	GREYMAP	MAPS
UCBSEND	TOMSEND	

RECENT ACTIVITIES

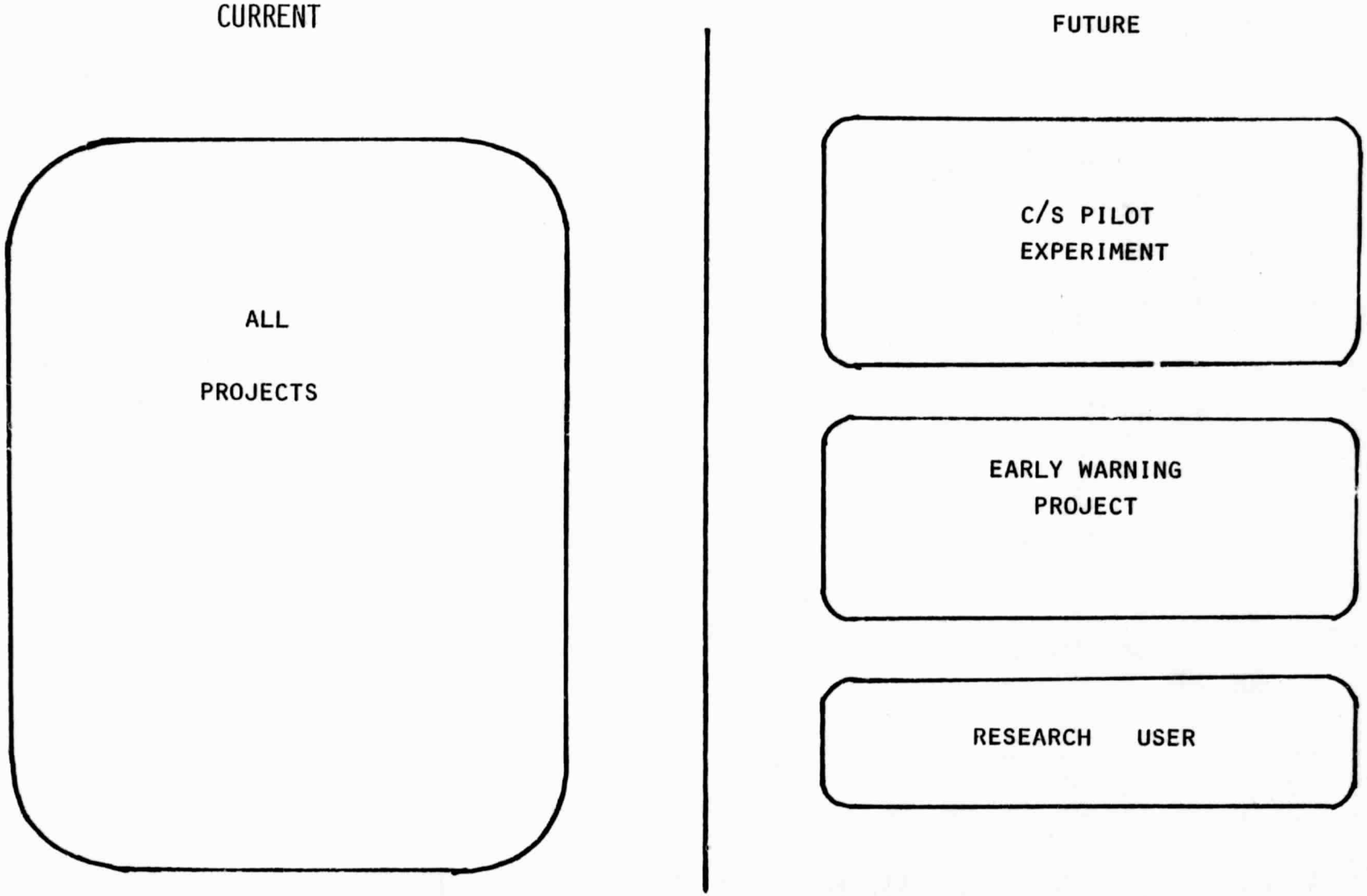
- ACCURACY ASSESSMENT SOFTWARE
- ADDITIONAL CAPABILITIES - GROUND TRUTH
  BLOB AND CLUSTER STATISTICS
- SYSTEM IMPROVEMENTS
  - CX ROUTINES - SCENARIO WRITING AID
  - LUCK - A DEBUGGING TOOL
- WHEAT/BARLEY LABELER
- HOOKING UP WITH RT&E DATABASE

ONGOING ACTIVITES

- Modifications for Baseline Version II
- Documentation
- Designing Approach to Handle
  - multiple workspaces
  - hierarchical organization of CHARLIE data entities
- Design of Research System Capabilities

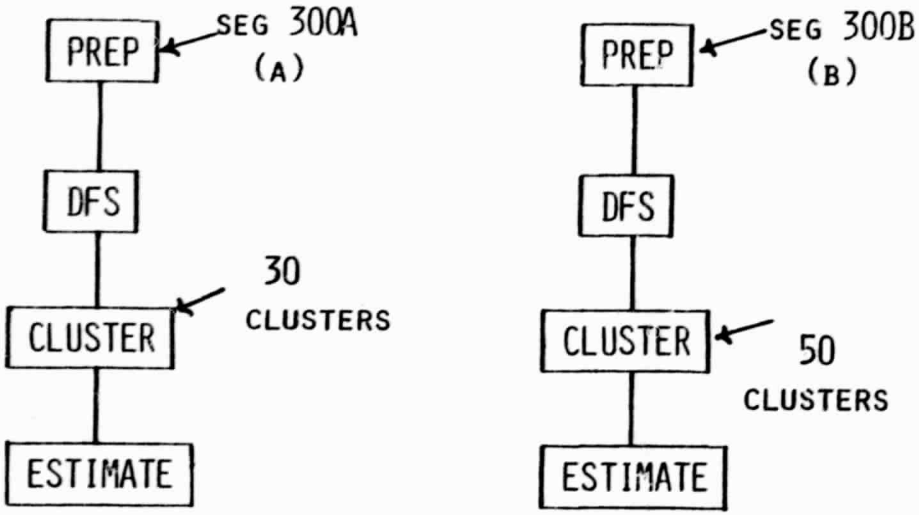

SYSTEM DOCUMENTATION
HOW TO USE BASELINE
HOW TO USE BASELINE

MULTIPLE WORKSPACES



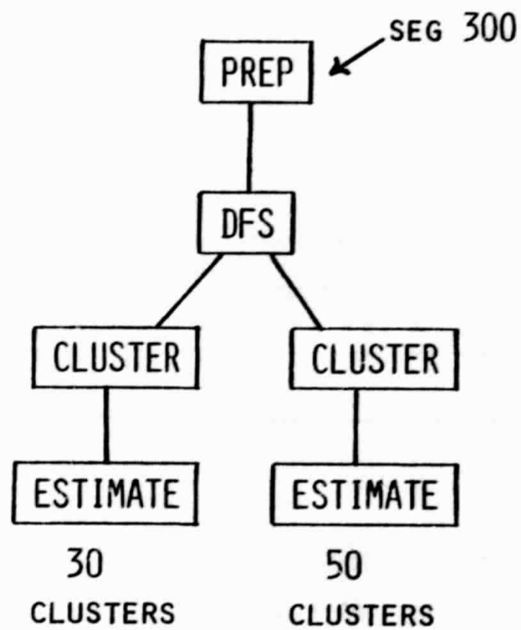
ORGANIZATION OF CHARLIE DATA ENTITIES

PRESENT



- DATA AND PROCESSING FOR PREP AND DFS IS DUPLICATED

FUTURE



- DUPLICATION REMOVED

FUTURE PLANS

- Implementation of
  - Multiple Workspaces
  - Hierarchical Charlie
- Implementation of Additional Application Software
- Design and Implementation of Research Capabilities

RECOMMENDATIONS

INCREASE THE AVAILABILITY, USE, AND KNOWLEDGE OF THE SOFTWARE SYSTEM.

ARGENTINA CONFUSION CROPS

ERIM/UCB FCPF Corn & Soybean Consortium

Byron Wood

Presented at

FCPF Quarterly Technical Interchange

July 1981

CONFUSION CROPS

OBJECTIVE:

TO DETERMINE TEMPORAL-SPECTRAL CROP CHARACTERISTICS, AS MEASURED BY LANDSAT, THAT WILL ALLOW ACCURATE AND CONSISTENT SEPARATION OF CORN AND SOYBEANS FROM CONFUSION CROPS.

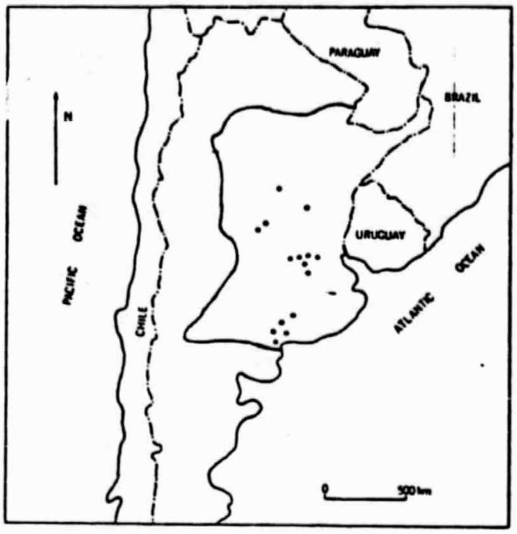
KEY ISSUE:

END-OF-SEASON CORN/SOYBEAN CLASSIFICATION TECHNIQUES HAVE BEEN DEVELOPED IN THE U.S. CORN BELT, WHERE CORN AND SOYBEANS ARE ESSENTIALLY THE ONLY SUMMER CROPS GROWN. TO EXTEND EXISTING PROCEDURES TO ARGENTINA, WHERE OTHER CROPS ARE GROWN AT THE SAME TIME, METHODS ARE NEEDED FOR EXCLUDING CONFUSION CROPS FROM THE CORN/SOYBEAN ESTIMATE.

CONFUSION CROPS

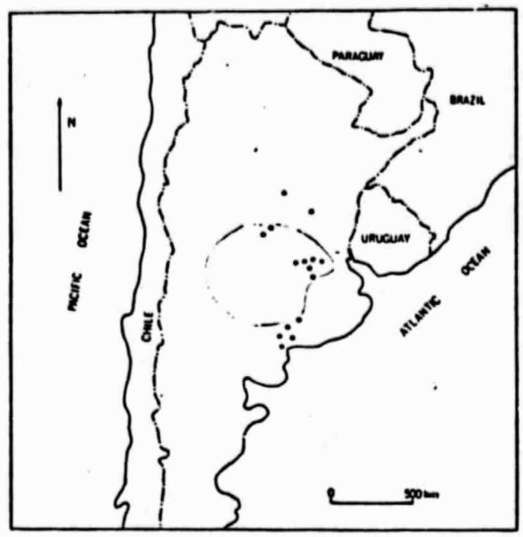
APPROACH:

- IDENTIFY CORN/SOYBEAN CONFUSION CROPS IN ARGENTINA
- BECOME FAMILIAR WITH CROP PHENOLOGY AND CROPPING PRACTICES
- SELECT CORN, SOYBEAN AND CONFUSION CROP FIELD SAMPLES
  - DATA SET PRIMARILY 1979; SOME 1977 AND 1978
  - EXHAUSTIVE SAMPLE OF CONFUSION CROP FIELDS
- NORMALIZE DATA AND EXTRACT TASSELLED CAP/GRABS
- GENERATE SPECTRAL AIDS OF LANDSAT TEMPORAL-SPECTRAL FEATURES
  - BINARY VEGETATION SEQUENCES (DFS)
  - GRABS VS. BRIGHTNESS SCATTERPLOTS (SINGLE DATES)
  - GRABS VS. BRIGHTNESS TRAJECTORIES (MULTIPLE DATES)
  - GRABS VS. TIME PROFILES
- EXAMINE FOR CHARACTERISTICS THAT WILL ALLOW CONSISTENT SEPARATION OF CONFUSION CROPS FROM CORN AND SOYBEANS



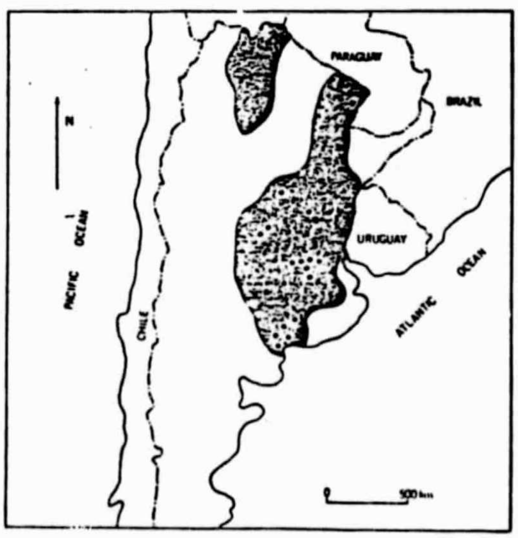
• SEGMENT WHERE GROUND DATA WERE COLLECTED

CORN



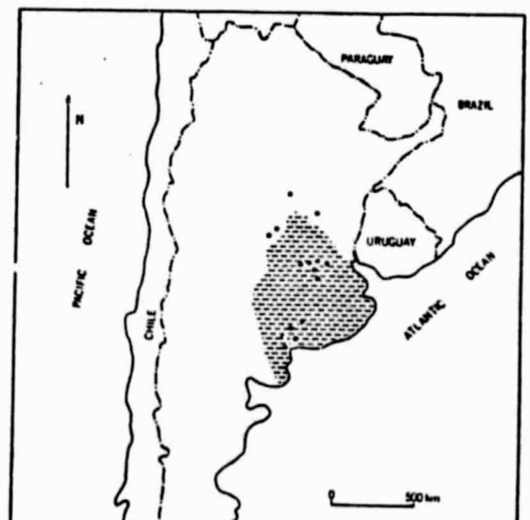
• SEGMENT WHERE GROUND DATA WERE COLLECTED

SOYBEANS



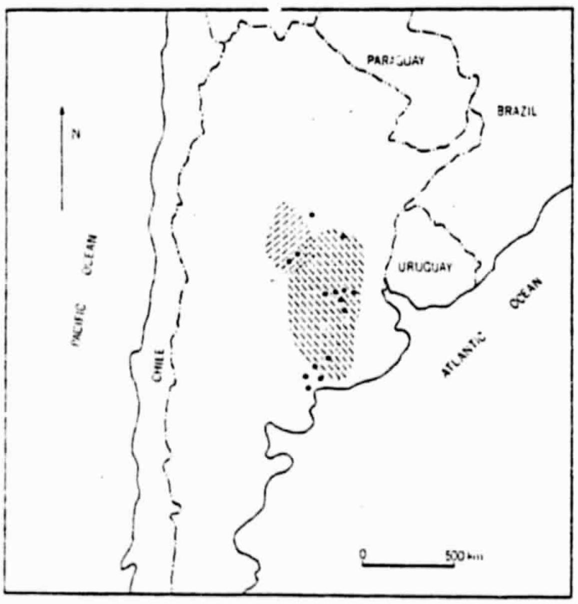
• SEGMENT WHERE GROUND DATA WERE COLLECTED

SORGHUM



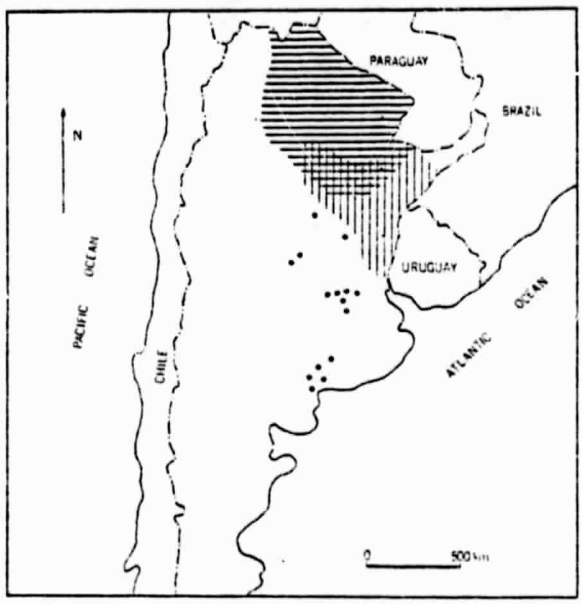
• SEGMENT WHERE GROUND DATA WERE COLLECTED

WHEAT



• SEGMENT WHERE GROUND DATA WERE COLLECTED

SUNFLOWERS PEANUTS



• SEGMENT WHERE GROUND DATA WERE COLLECTED

COTTON RICE

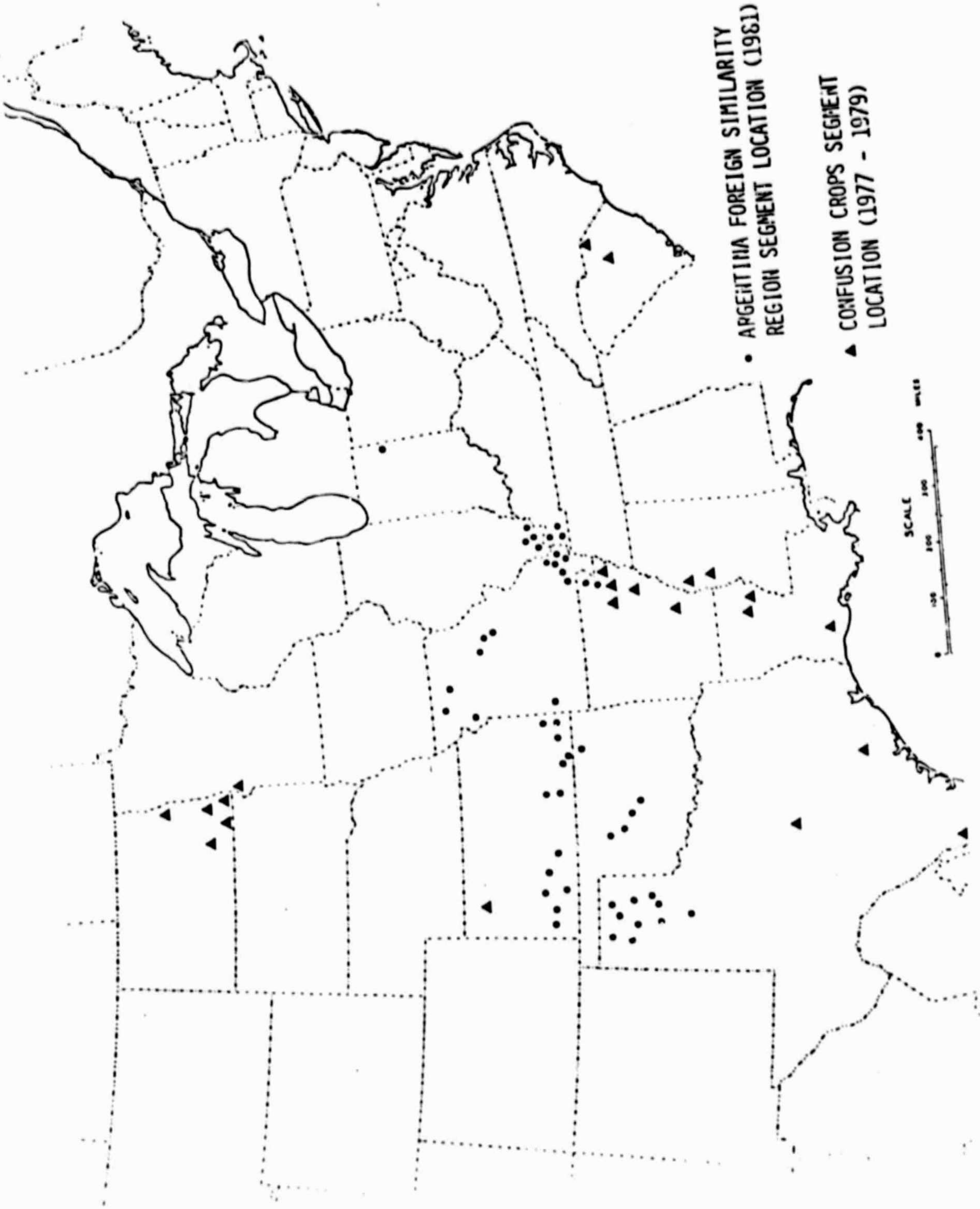
APPROACH (CONT'D.):

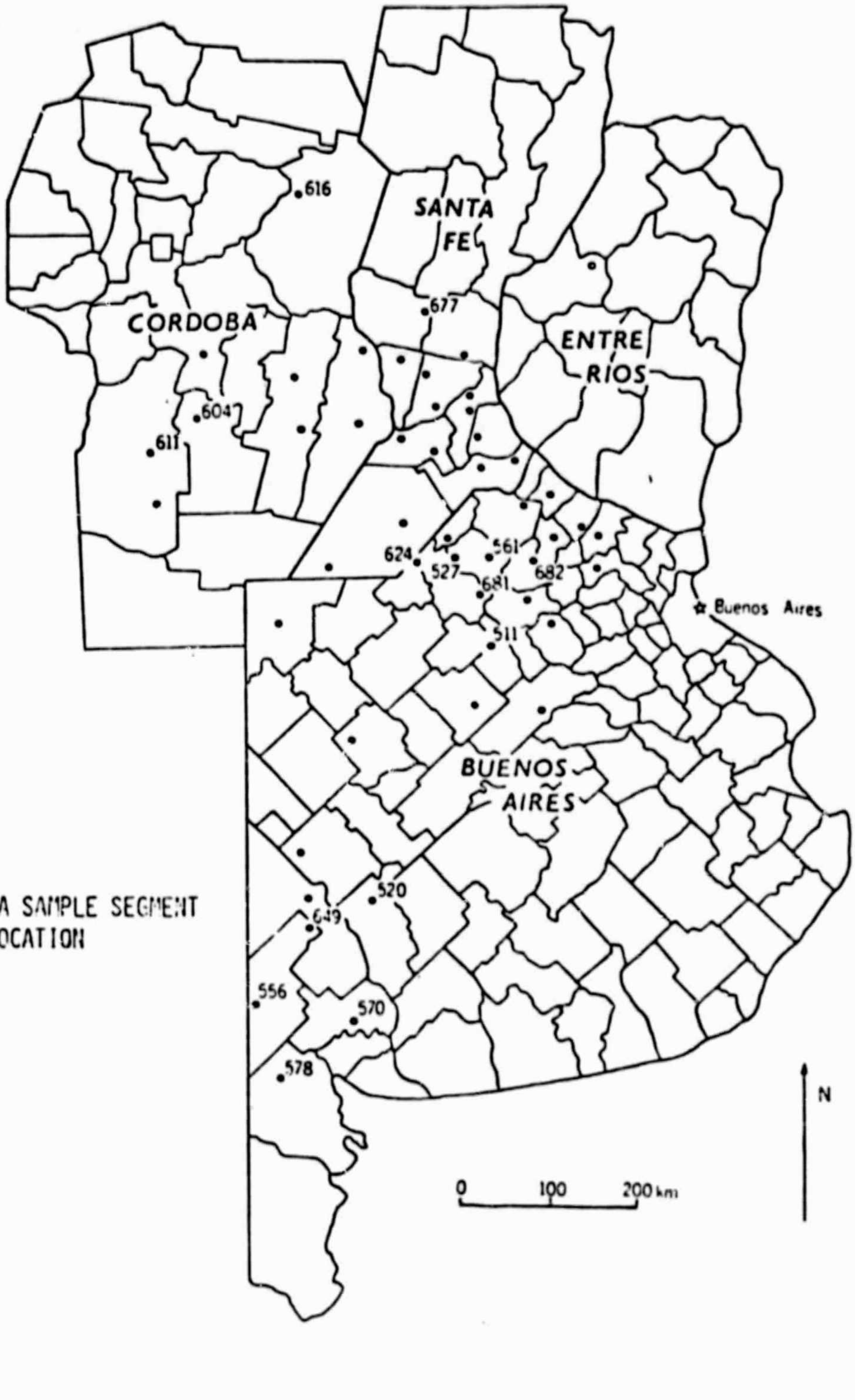
- FORMULATE GUIDELINES FOR ACCURATE IDENTIFICATION OF CORN AND SOYBEANS IN THE PRESENCE OF CONFUSION CROPS
- MODIFY BASELINE OR OTHER END-OF-SEASON PROCEDURES ACCORDINGLY

CONFUSION CROPS SEGMENTS

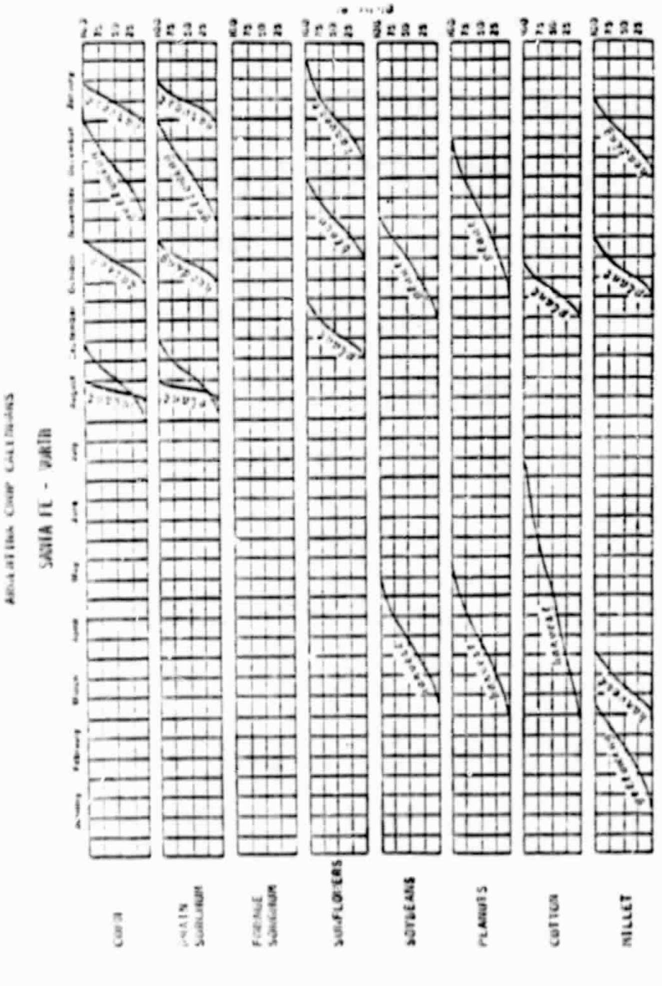
SEGMENT #	LOCATION	CROP MIX*	YEAR
268	JEFF DAVIS, LA.	SY, RI	1979
273	FRANKLIN, LA.	SY, CT	1979
274	TENSAS, LA.	SY, CT	1979
276	WHARTON, TX.	SY, RI, SR	1979
286	BELL, TX.	CR, SR	1979
292	HIDALGO, TX.	CR, SR, CT, SU, SC	1979
302	ST. FRANCIS, ARK.	SY, RI	1979
304	POINSETT, ARK.	SY, RI	1979
305	ARKANSAS, ARK.	SY, RI	1979
306	MISSISSIPPI, ARK.	SY, RI, CT	1979
338	MARLBORO, S.C.	CR, SY, CT, TB	1979
1023	THOMAS, KAN.	CR, SR, SY	1978
1473	CASS, N.D.	SY, SU, SB	1978
1619	GRAND FORKS, N.D.	SU, SB, BN, BN, CR, PT	1977-1978
1664	SARGENT, N.D.	CR, SU	1978
303	JACKSON, ARK.	SY, SR, RI, CT	1979
339	LEE, S.C.	SY, CR, CT	1979
1640	BARNES, N.D.	CR, SU	1977
1663	RICHLAND, N.D.	CR, SY, SU, SB	1977
1927	SARGENT, N.D.	CR, SU	1977
135	TRAVERSE, MINN.	SY, CR, SU, SB	1978
196	SHARKEY, MISS.	SY, CT, RI	1978
812	BOLIVAR, MISS.	SY, CT, RI	1978

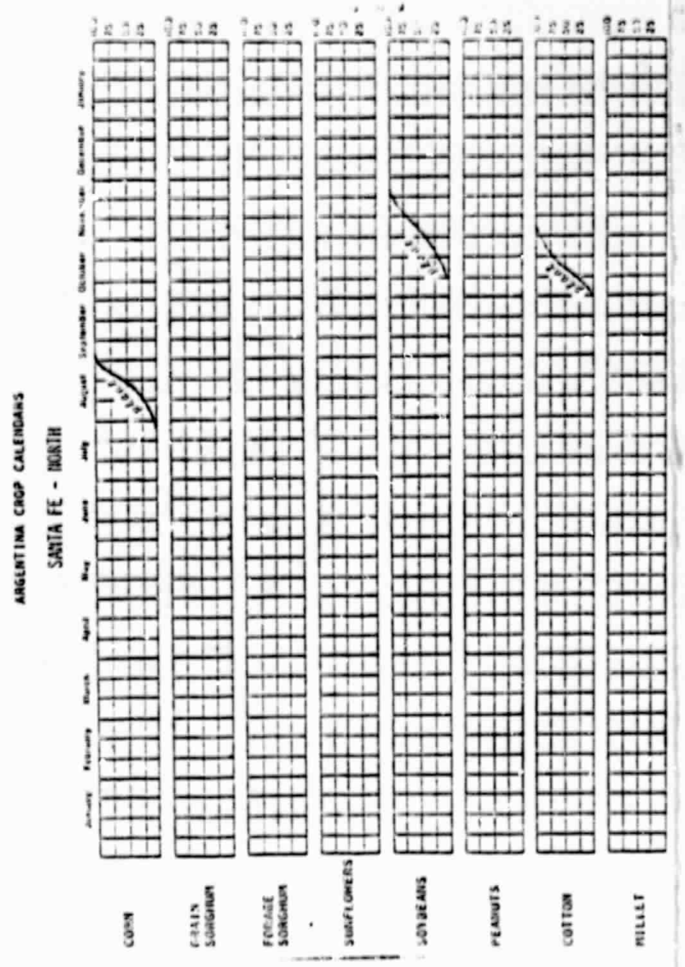
* BN = BEANS, CR = CORN, CT = COTTON, PT = POTATOES, RI = RICE, SB = SUGAR BEETS, SR = SORGHUM, SU = SUNFLOWERS, SY = SOYBEANS, TB = TOBACCO

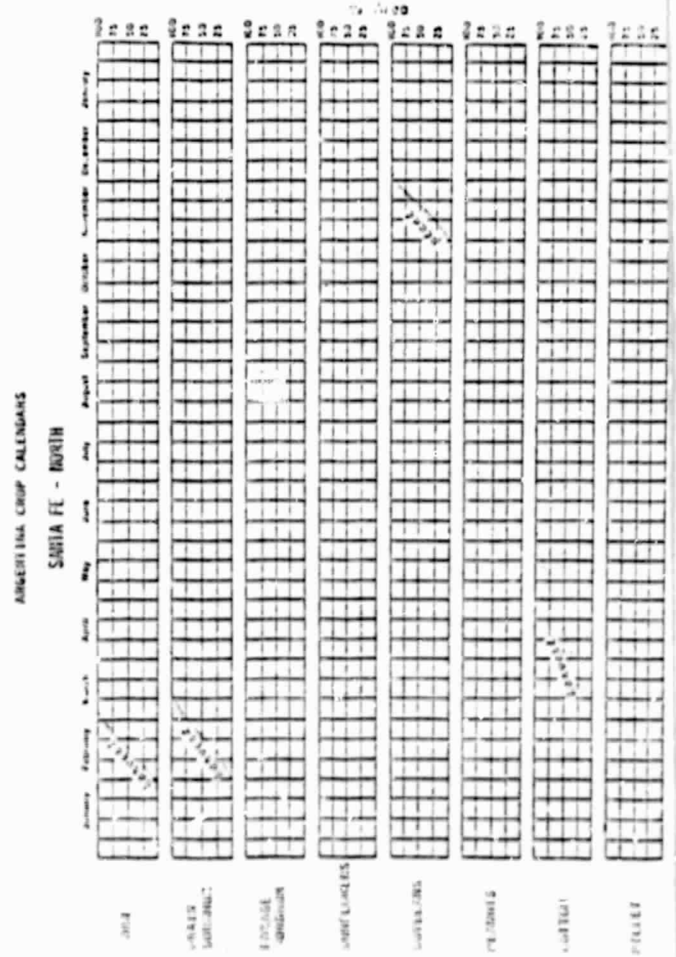

• ARGENTINA FOREIGN SIMILARITY REGION SEGMENT LOCATION (1981)
▲ CONFUSION CROPS SEGMENT LOCATION (1977 - 1979)
SCALE



ARGENTINA SAMPLE SEGMENT LOCATION

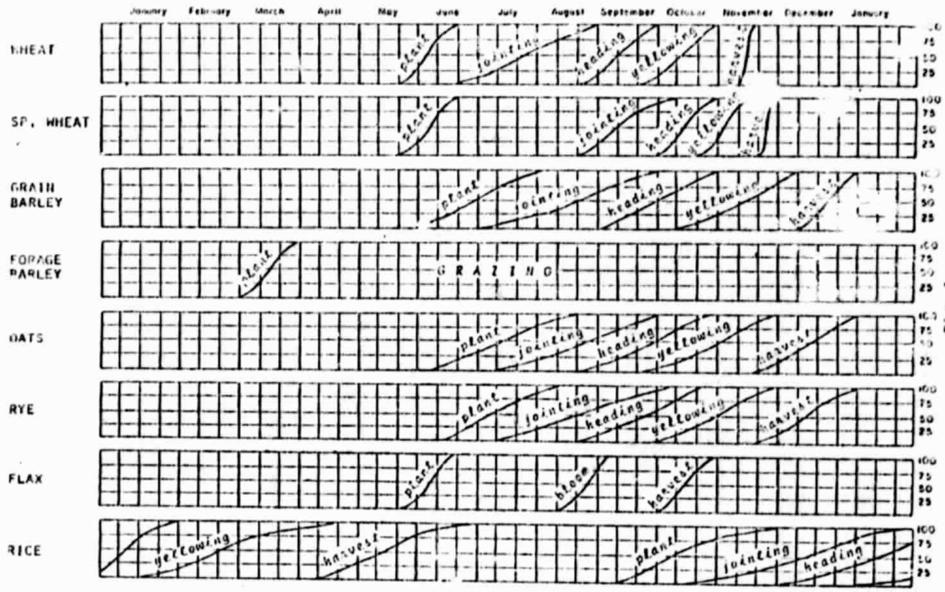

ARGENTINA CROP CALENDARS
SANTA FE - NORTH
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
COTTON
MILLET


ARGENTINA CROP CALENDARS
SANTA FE - NORTH
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
COTTON
MILLET


ARGENTINA CROP CALENDARS
SANTA FE - NORTH

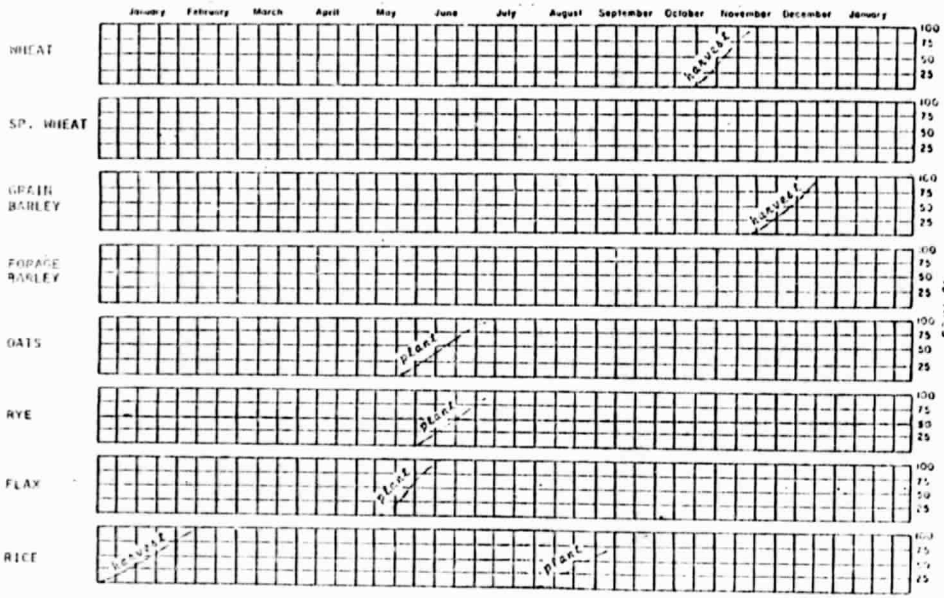
ARGENTINA CROP CALENDARS

SANTA FE - NORTH



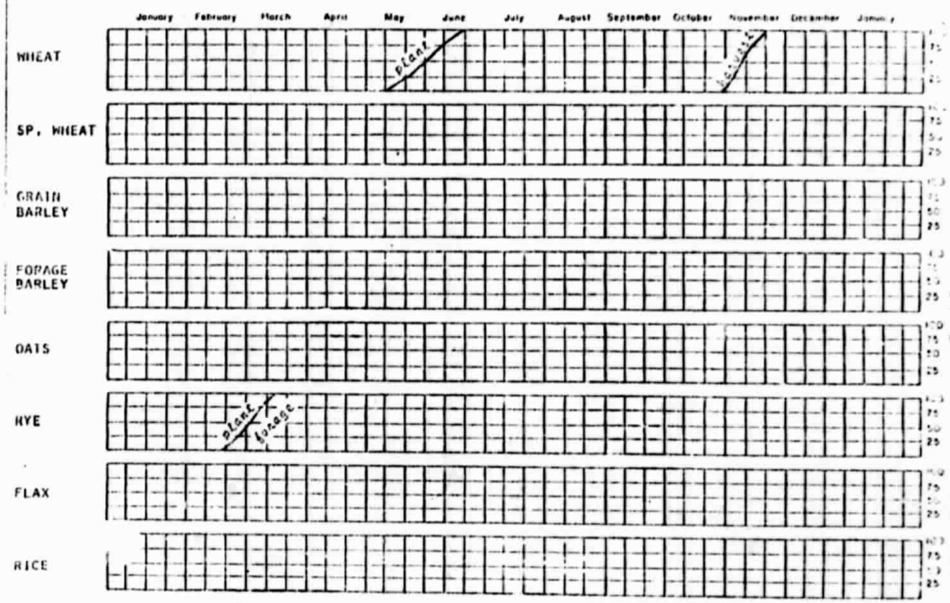
ARGENTINA CROP CALENDARS

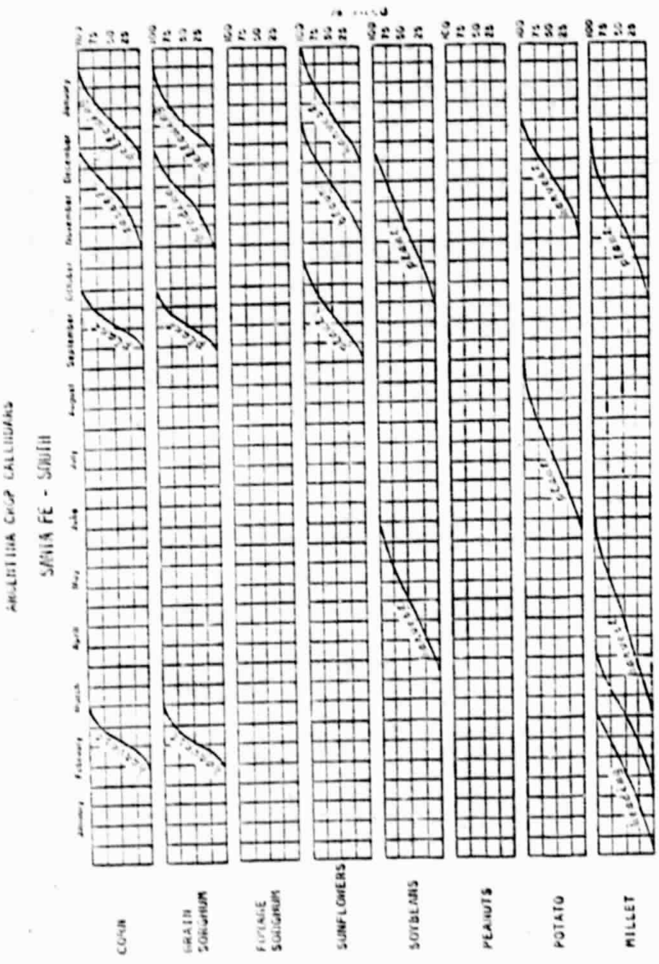
SANTA FE - NORTH

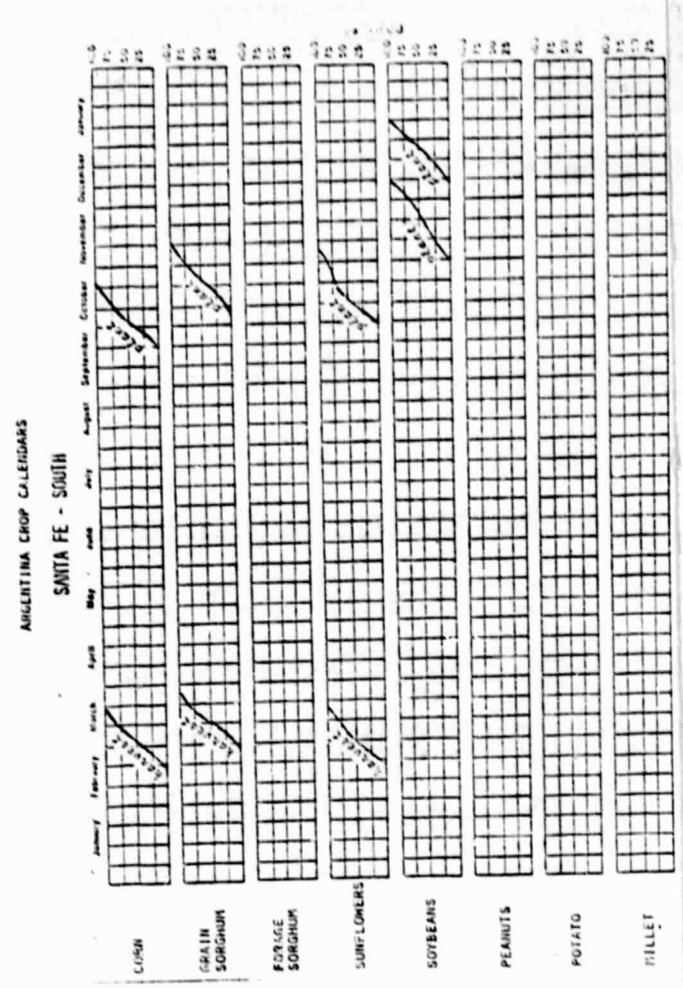


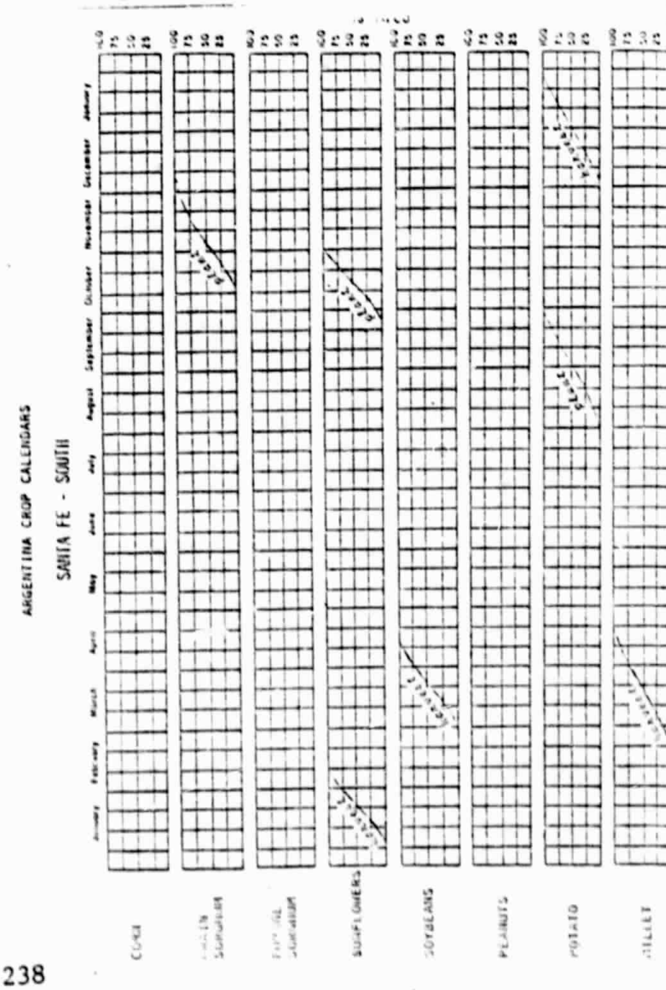
ARGENTINA CROP CALENDARS

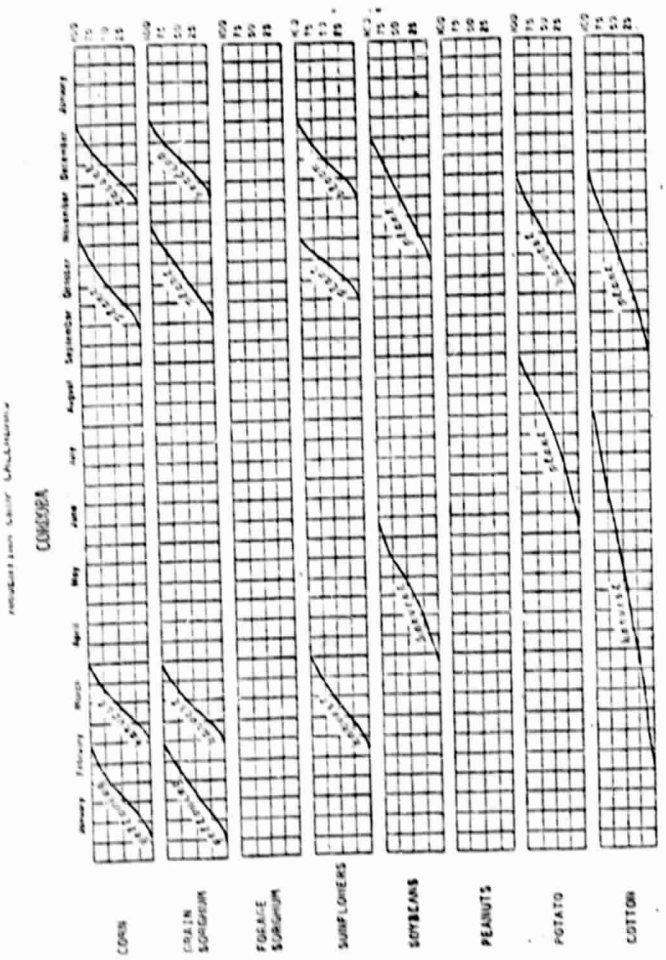
SANTA FE - NORTH

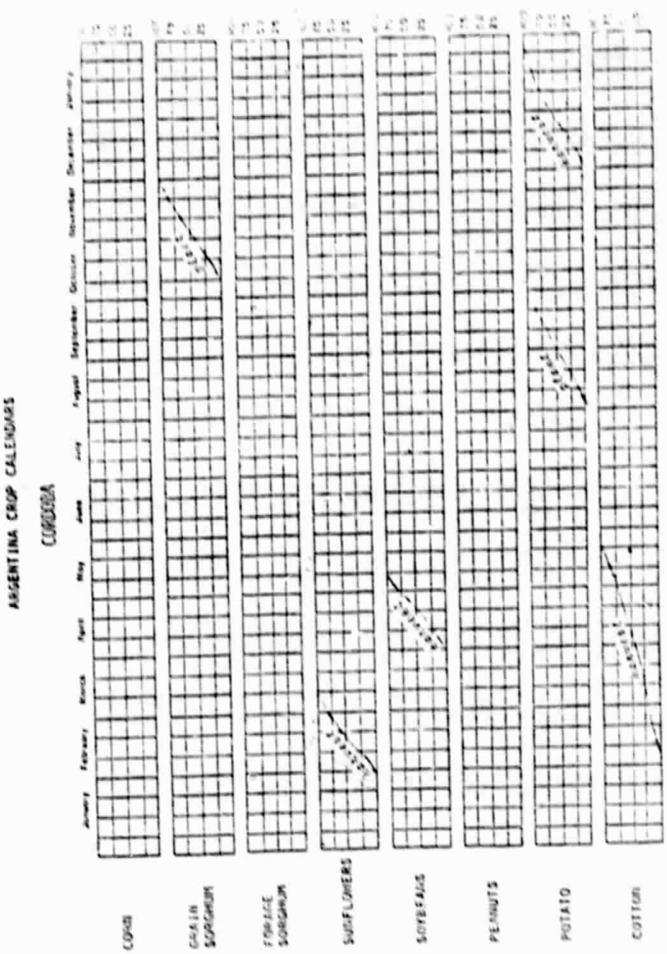


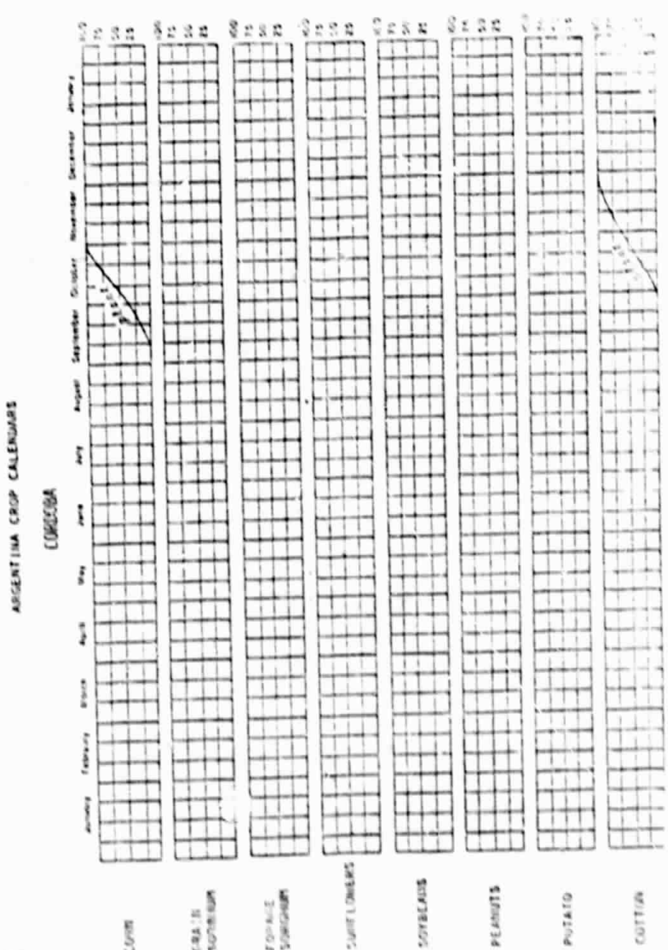

ARGENTINA CROP CALENDARS
SANTA FE - SOUTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
MILLET
100
75
50
25

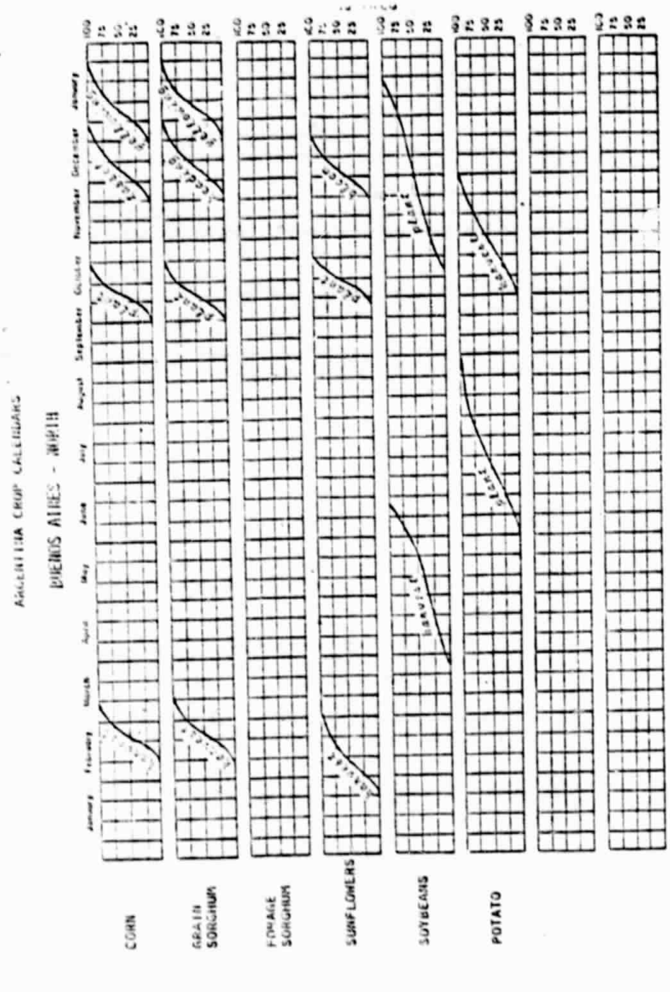

ARGENTINA CROP CALENDARS
SANTA FE - SOUTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
MILLET
100
75
50
25

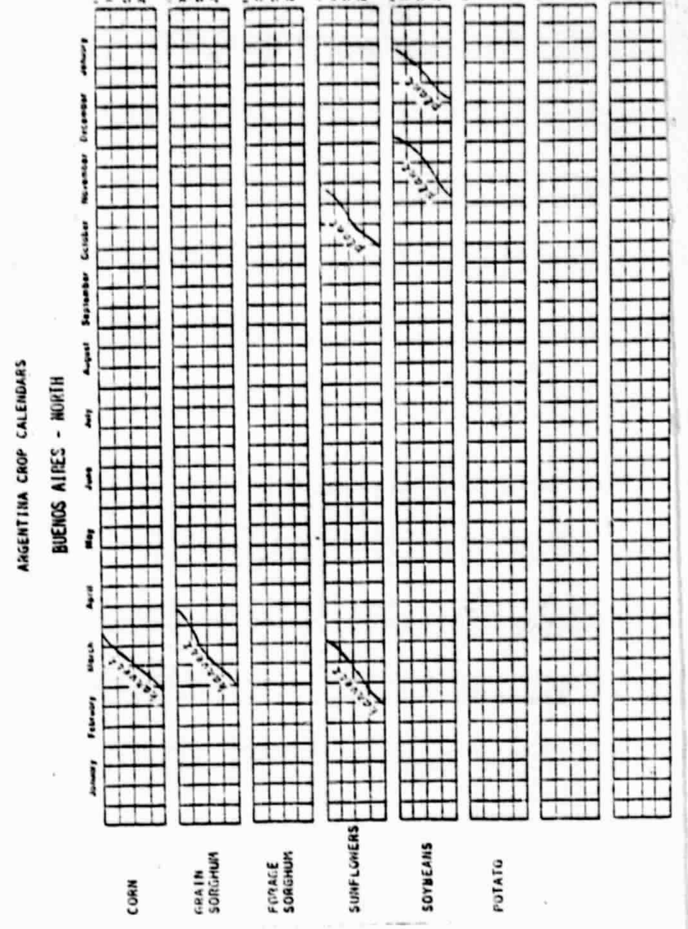

ARGENTINA CROP CALENDARS
SANTA FE - SOUTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
MILLET
100
75
50
25

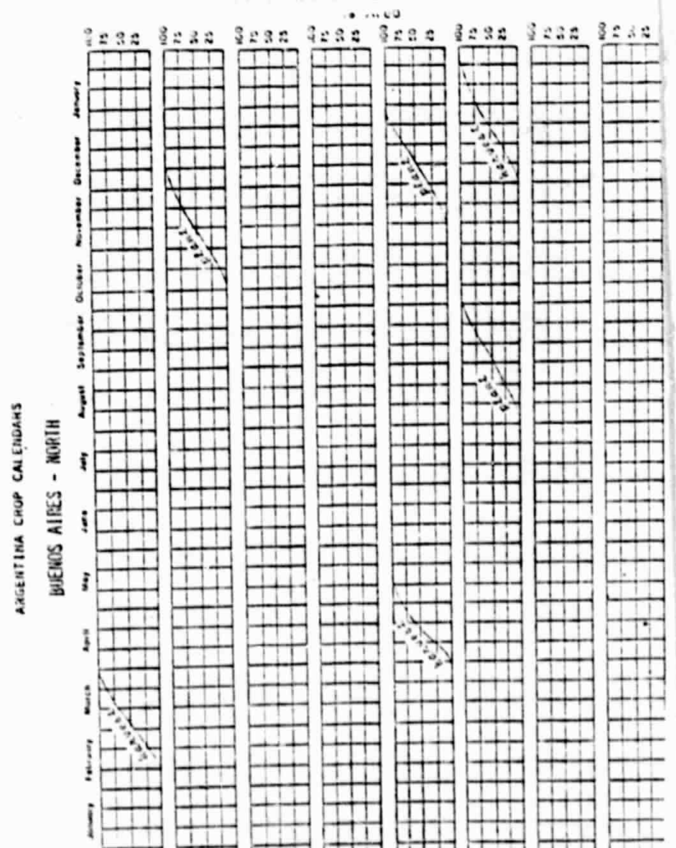

CORDOBA
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
COTTON


ARGENTINA CROP CALENDARS
CORDOBA
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
COTTON


ARGENTINA CROP CALENDARS
CORDOBA
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
PEANUTS
POTATO
COTTON


ARGENTINA CROP CALENDARS
BUENOS AIRES - NORTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
POTATO
plant
harvest
100
75
50
25


ARGENTINA CROP CALENDARS
BUENOS AIRES - NORTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
SOYBEANS
POTATO
plant
harvest
100
75
50
25


ARGENTINA CROP CALENDARS
BUENOS AIRES - NORTH
January February March April May June July August September October November December January
CORN
GRAIN SORGHUM
FORAGE SORGHUM
SUNFLOWERS
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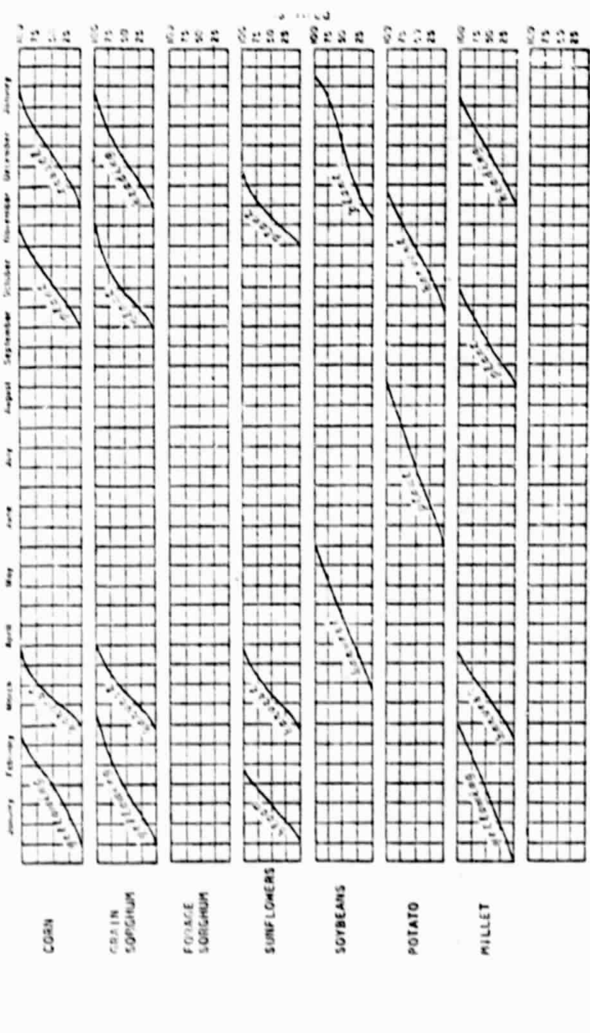
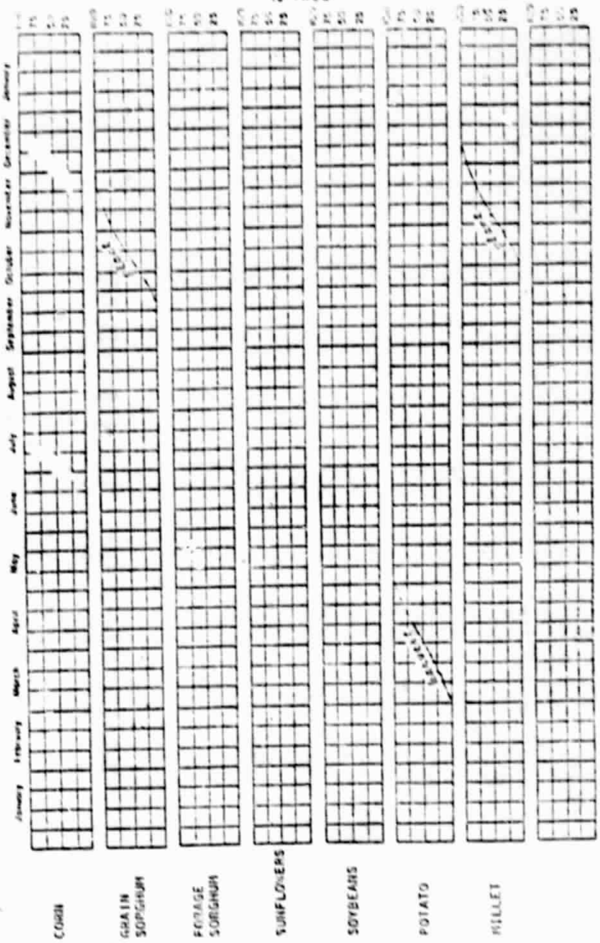
POTATO
plant
harvest
100
75
50
25

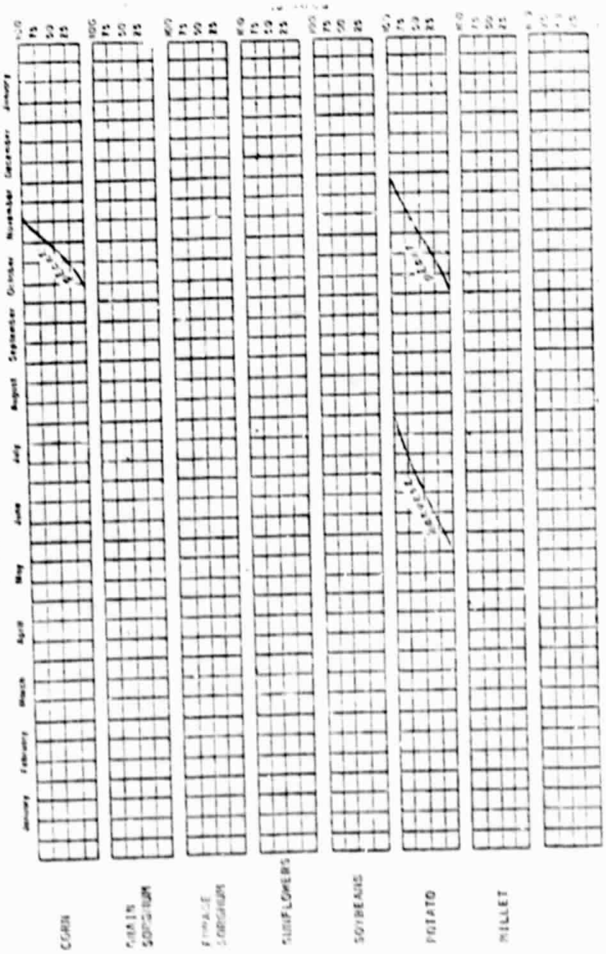
ARGENTINA CROP CALENDARS
BUENOS AIRES - SOUTH



ARGENTINA CROP CALENDARS
BUENOS AIRES - SOUTH



ARGENTINA CROP CALENDARS
BUENOS AIRES - SOUTH



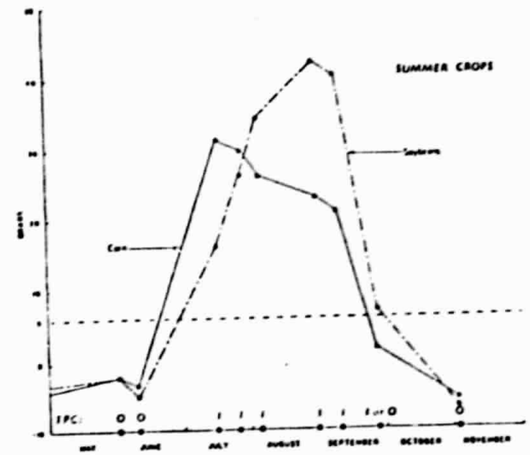
CONFUSION CROPS

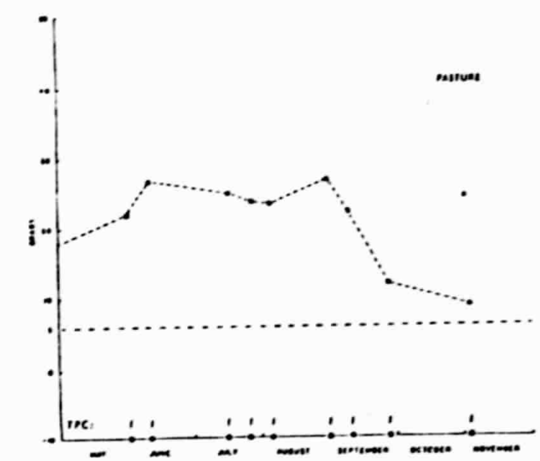
IDENTIFICATION OF CORN AND SOYBEANS

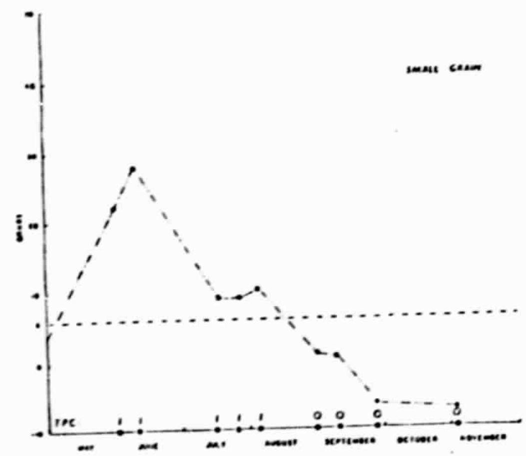
- TEMPORAL CRITERIA USED TO SEPARATE AGGREGATES OF CROPS WITH SIMILAR CROP CALENDARS
  - CORN AND SOYBEANS ARE TEMPORALLY OUT-OF-PHASE WITH OTHER CROP GROUPS SUCH AS SMALL GRAINS AND PASTURE
- SPECTRAL CRITERIA THEN USED TO SEPARATE CORN FROM SOYBEANS
  - SOYBEANS GENERALLY HAVE HIGHER GRABS AND BRIGHTNESS VALUES THAN CORN

SEPARATING SUMMER CROPS FROM OTHER BASED ON
TEMPORAL PATTERN

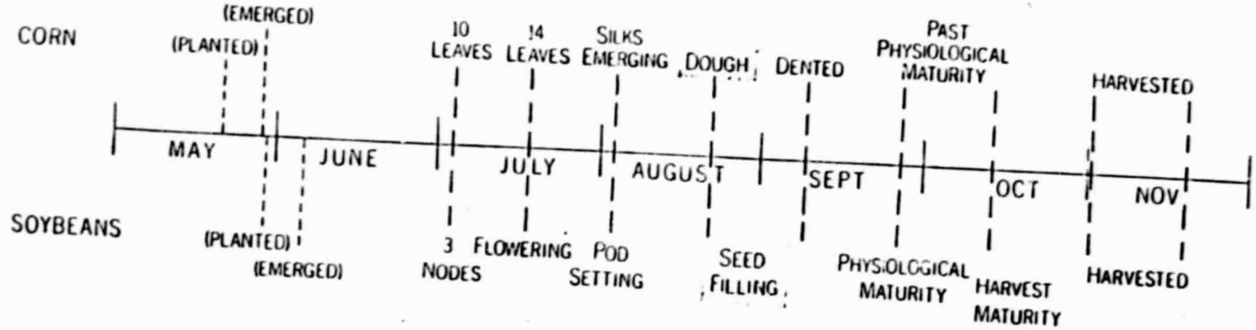
CENTPAL U.S. CORN BELT

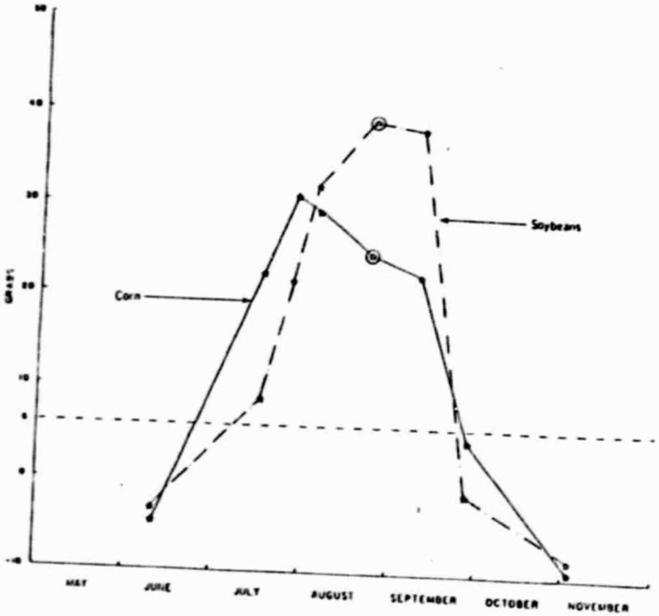


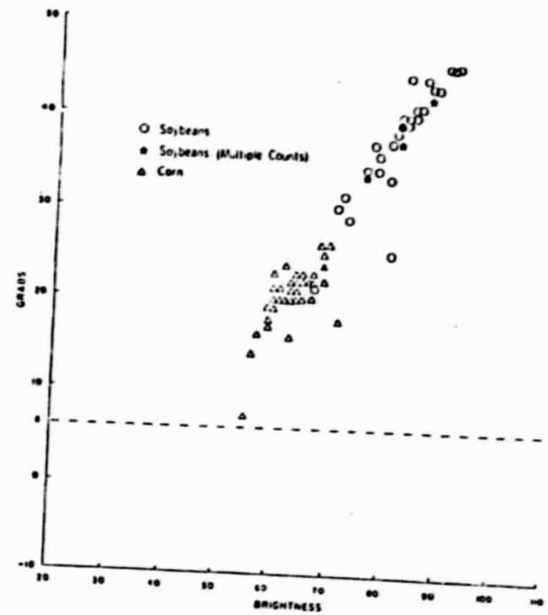




SEPARATING CORN FROM SOYBEANS BASED ON SPECTRAL AMPLITUDES (MAXIMUM GREENNESS OR GRABS)
CENTRAL U.S. CORN BELT





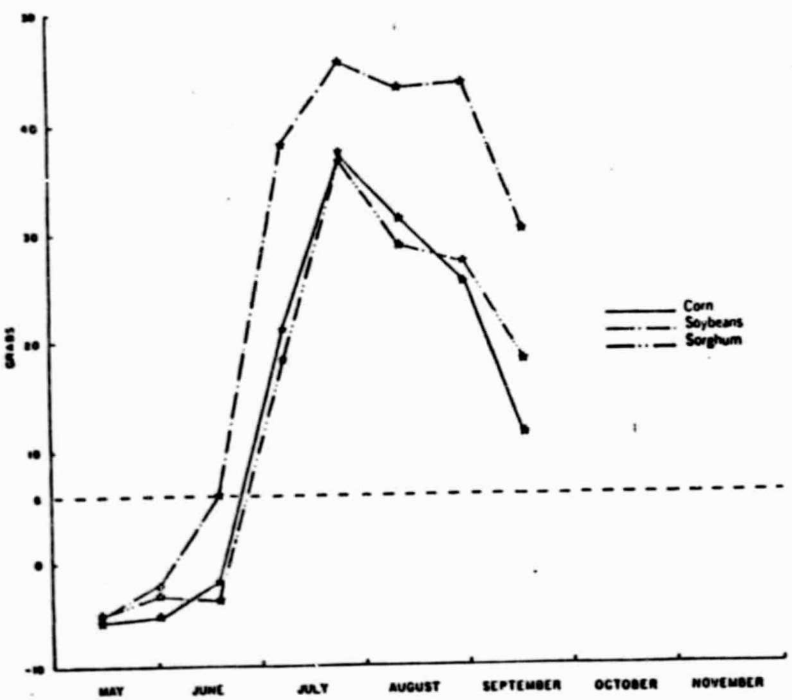


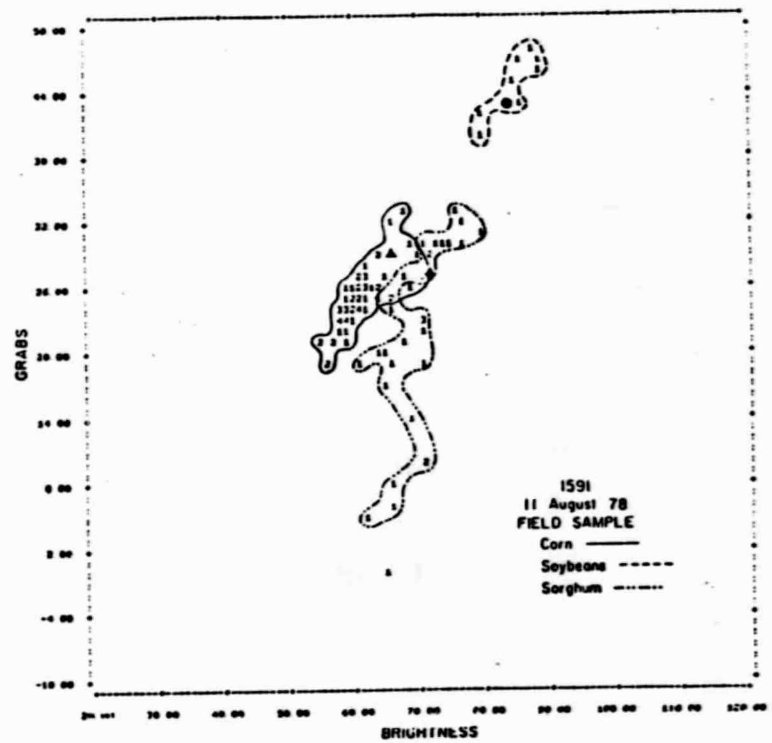
CONFUSION CROPS

PRELIMINARY OBSERVATIONS FROM 1978 AND 1979 UCB STUDIES

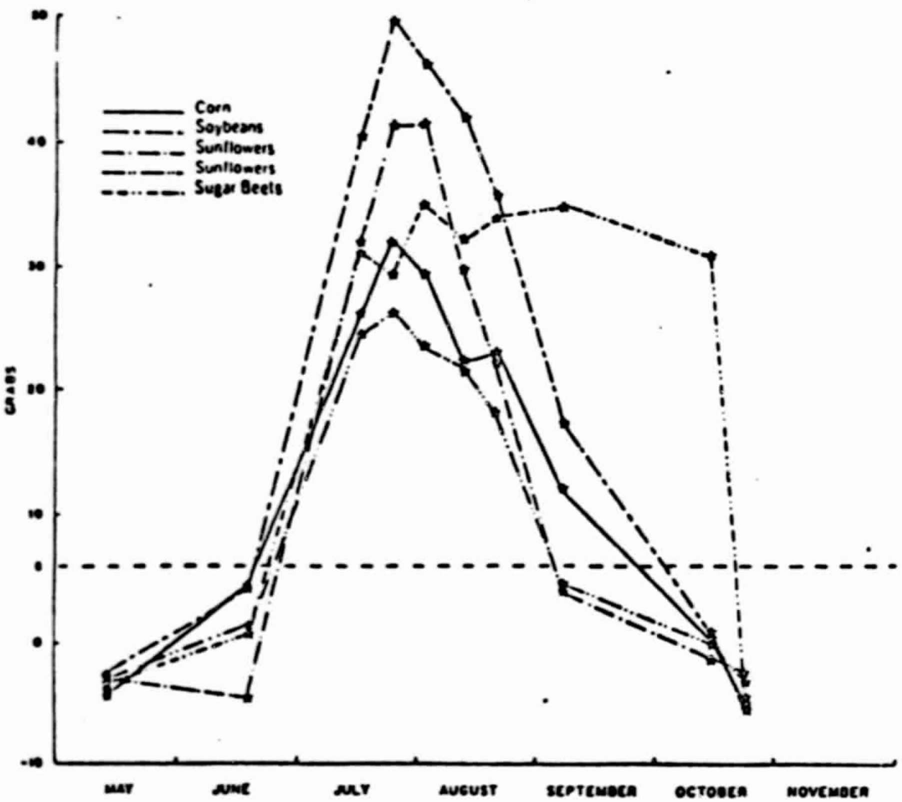
- SUNFLOWERS
  - MAXIMUM VEGETATION INDICATOR (VI) AMPLITUDES OFTEN HIGHER THAN CORN AND LOWER THAN SOYBEANS, BUT NOT CONSISTENTLY SO
  - BRIGHTNESS VALUES GENERALLY HIGHER THAN CORN AND SOYBEANS FOR GIVEN VI VALUE ("PARALLEL GREEN ARM")
  - TEMPORAL DEVELOPMENT PROFILES APPEAR SIMILAR
- SORGHUM
  - TEMPORAL DEVELOPMENT PROFILE SIMILAR TO CORN, BUT PERHAPS SLIGHTLY LATER (NO COMPARISON MADE TO SOYBEAN PROFILE)
  - MAXIMUM VI AMPLITUDES LOWER THAN SOYBEANS
  - MAXIMUM VI AMPLITUDES LOWER THAN CORN ONLY WHEN CORN IS IRRIGATED AND SORGHUM IS NOT
  - UNIRRIGATED SORGHUM GENERALLY BRIGHTER THAN CORN

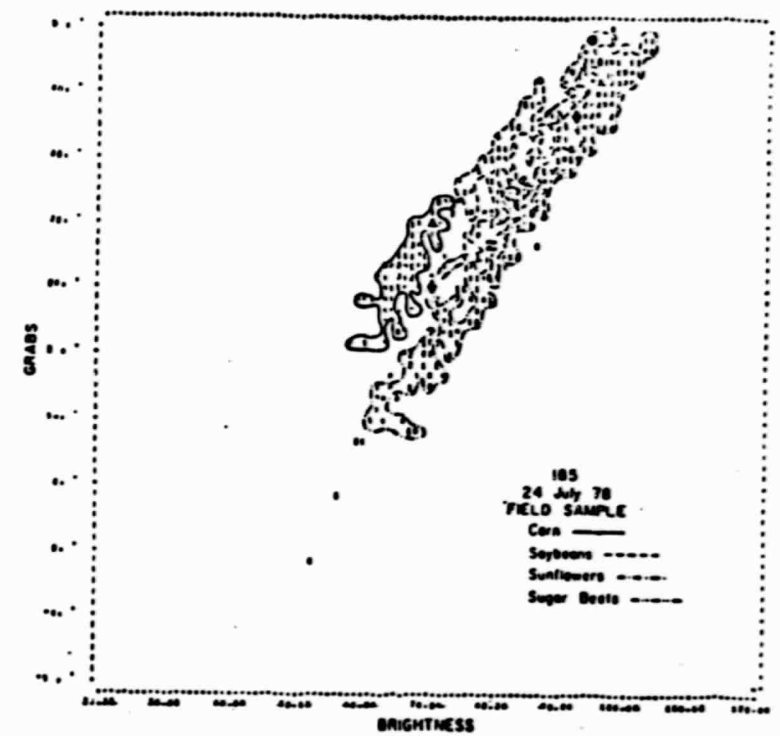
SORGHUM AS A POTENTIAL CONFUSION CROP RELATIVE TO CORN
SEGMENT 1591, WEBSTER, NEBRASKA





SUNFLOWERS AS A POTENTIAL CONFUSION CROP RELATIVE TO CORN AND SOYBEANS
SEGMENT 185, TRAVERSE, MINNESOTA





ESTIMATION USING PROFILE TECHNIQUES

D. Witte

Presented at

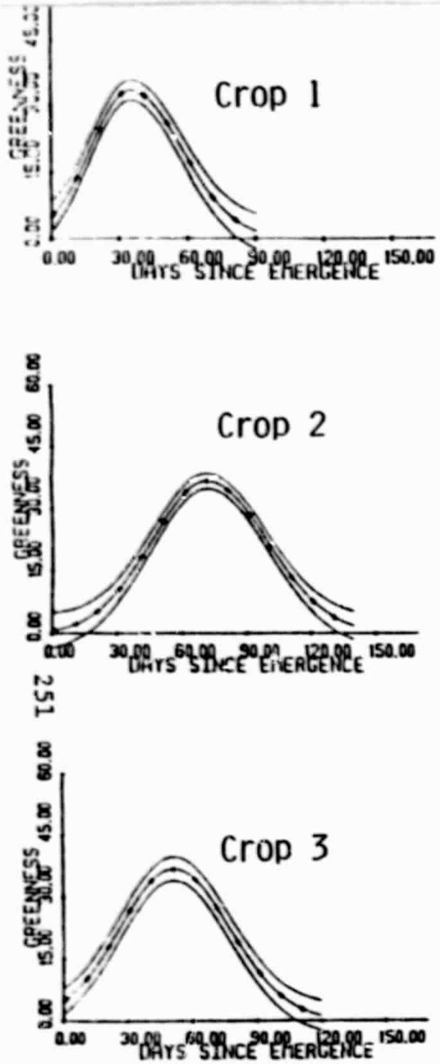
FCPF Quarterly Technical Interchange

July 1981

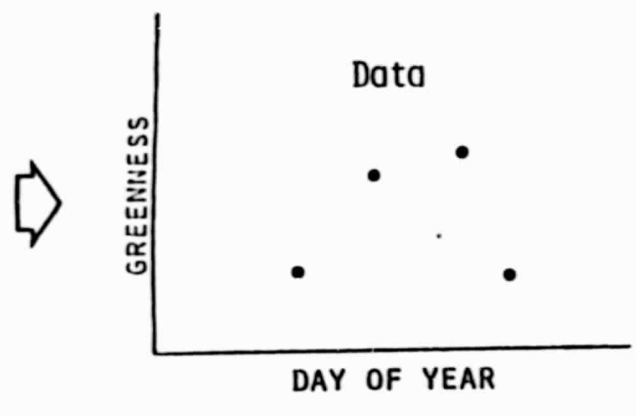
CHARACTERISTICS OF PROFILE TECHNIQUES

- Attempt to Reconstruct the Continuous Temporal Behavior of Some Target Feature Based on a Set of Discrete Time Samples
- Require Some Level of Modeling of the Feature of Interest
- Are Machine Intensive
- Ideally Allow for Automatic Classification/Labeling of Some Elements

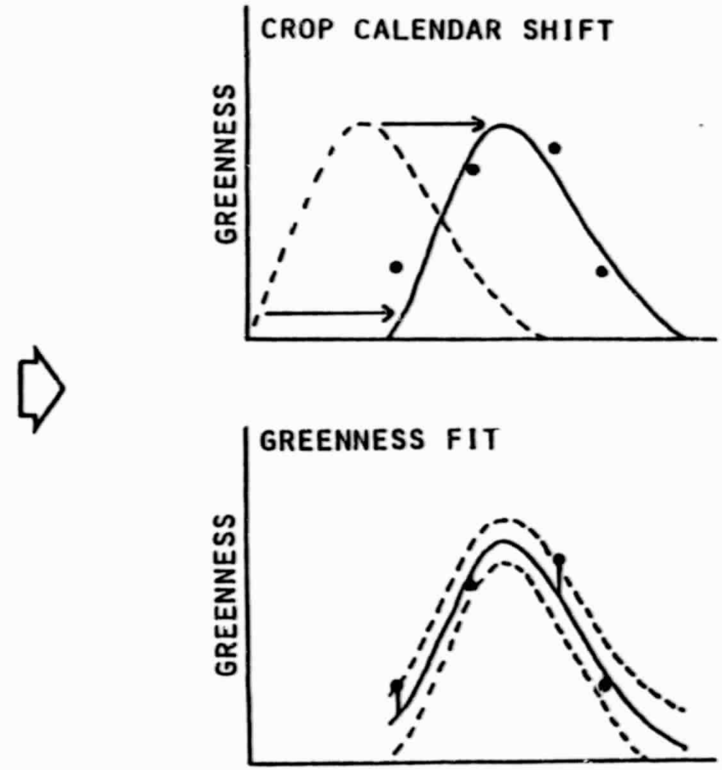
TECHNIQUE NO. 1: PROFILE MATCHING



Pre-defined Profile Models

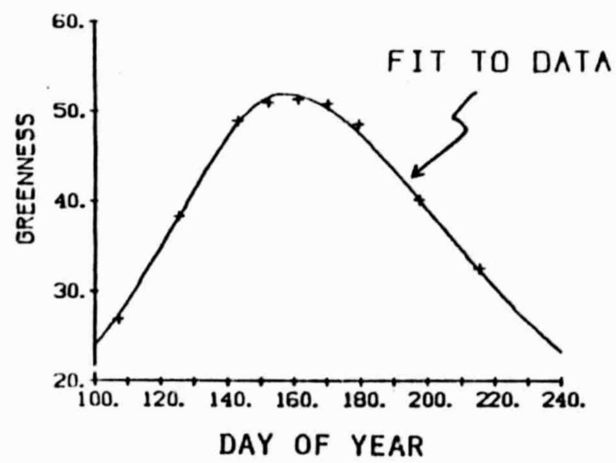


COMPARED TO PROFILES
FOR EACH CROP 1



1) Compute time shift for data
2) Compute goodness-of-fit with each crop model profile
3) Based on 1) and 2) determine most probable crop type represented by data
4) Generate area estimates based on classifications

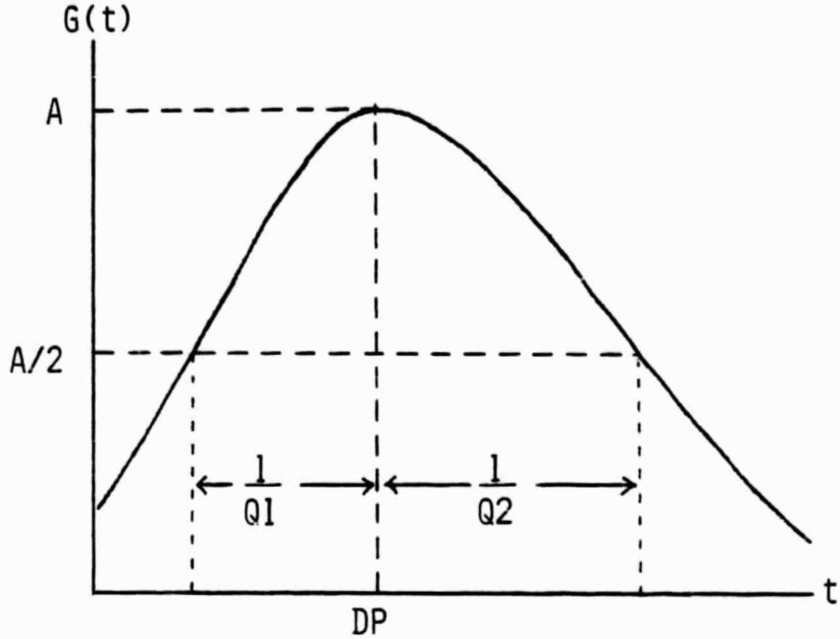
TECHNIQUE NO. 2: PROFILE FITTING/FEATURE EXTRACTION



1) Fit variable-parameter model form, $f(a_1 \ldots a_n)$, to data; $a_1 \ldots a_n$ = model parameters
2) Define n-dimensional feature space spanned by parameter values $a_1 \ldots a_n$ computed for all scene elements
3) Classify scene elements based on their parameter values
4) Generate area estimates based on classification

MODEL FORM USED

- Two-piece Sigmoidal Model
- Used to Fit Tasseled-Cap Variable Greenness as a Function of Time



$$G(t) = \begin{cases} \dfrac{A}{1 + Q1^2(t - DP)^2}, & t < DP \\[2ex] \dfrac{A}{1 + Q2^2(t - DP)^2}, & t \geq DP \end{cases}$$

Interpretation of Parameters:

DP = day of peak Greenness

A = peak Greenness value; i.e., G(t = DP)

Q1 = emergence to peak "Green-up" rate parameter

Q2 = peak to harvest "Green-down" rate parameter

PROFILE FITTING PROCESS

- Utilizes Non-Linear Regression Algorithm
- Estimates Four Model Parameters: DP, A, Q1, and Q2
- Estimation of DP, Day of Peak, is Equivalent to Computing Crop Calendar Shift
- Computes Measure of Goodness-of-Fit to Data
- Goodness-of-Fit and the Four Model Parameters Define a Five-Dimensional Feature Space

OBJECTIVES OF CURRENT PROFILE FITTING EFFORTS

- Evaluate Overall Potential of Profile Fitting to Area Estimation
- Identify Parameters/Features that Best Discriminate Between Crop Classes and Crop Types
- Determine Feasibility of Automatic Scene Classification
- Gain Further Insight into the Variability of Corn/Soybeans Features

APPROACHES

- Profile Fit Spectral Means of all Blobs in a Segment to Determine Fitting Efficiency
- Analyze Parameter/Feature Space for Separability of Crop Classes and Types
- Restrict Above Analysis to Big Blobs Whose Interior Purity Exceeds 5/6 so as to Avoid Impure Signatures
- Assess Accuracy of Automatic Classification of Big Blobs Based on Results of Separability Analysis

DATA SET

The Following 11 Segments were Analyzed in the Profile Fitting Efforts

Segment Number	County	State
123	Hamilton	Indiana
141	Madison	Iowa
202	Atchinson	Missouri
205	Clark	Missouri
800	Clinton	Iowa
832	Adams	Indiana
842	Henry	Indiana
852	Randolf	Indiana
853	Randolf	Indiana
877	Ida	Iowa
881	Monona	Iowa

COMPARISON OF BASELINE C/S PROCEDURE TO PROFILE FITTING

Baseline	
• Analyst Required; Relatively Slow	• No Analyst Required; Much Faster
• Only a Sample of Blobs are Labeled	• All Big Blobs are Fit and Classified
• Requires Accurate Crop Calendar Information	• No Crop Calendar Required; Computes Crop Calendar Shift for All Big Blobs
• Requires Analyst Interpretation of Image Products	• Requires No Image Products
• Separates Corn and Soy Based on One Acquisition and Qualitative Assessment of Spectral Behavior	• Separates Corn and Soy Based on Parameters Computed by Considering Several Acquisitions; Variations Due to Differences in Planting Dates are Virtually Eliminated

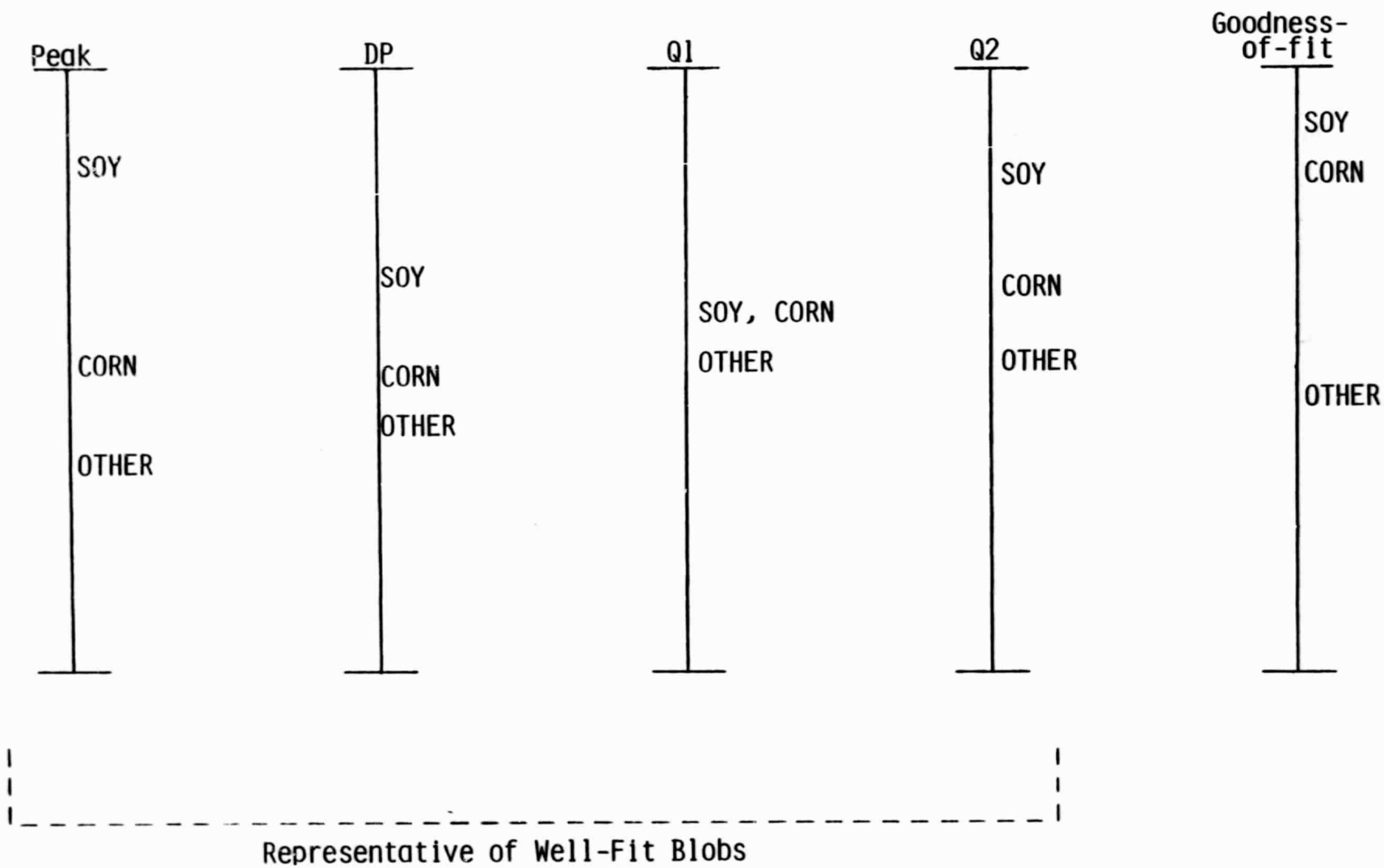
SUMMARY OF PROFILE FITTING EFFICIENCY

G-O-F = measure of Goodness-of-Fit

Class	# of Blobs	% Not Fit	% G-O-F < 0.75	% G-O-F ≥ 0.75
All Blobs	15,134	16.5	20.2	63.3
All Big Blobs	5,343	16.8	14.4	68.8
All Little Blobs	9,791	16.4	23.4	60.2
Pure Big Corn	1,134	2.9	8.2	88.9
Pure Big Soy	1,334	1.9	5.3	92.8
Pure Big Vegetated Non-Agricultural	943	53.7	22.6	23.7
Pure Big Unvegetated Non-Agricultural	170	27.1	33.5	39.4
Pure Little Corn	308	8.8	18.6	72.6
Pure Little Soy	1,745	5.9	16.0	78.1
Pure Little Vegetated Non-Agricultural	1,229	31.5	29.2	39.3
Pure Little Un-vegetated Non-Agricultural	361	31.7	34.2	34.1

ORIGINAL PAGE IS OF POOR QUALITY

GENERAL RELATIONSHIPS OF CORN/SOY/OTHER IN FEATURE SPACE



SUMMARY OF AUTOMATIC CLASSIFICATION EXPERIMENT

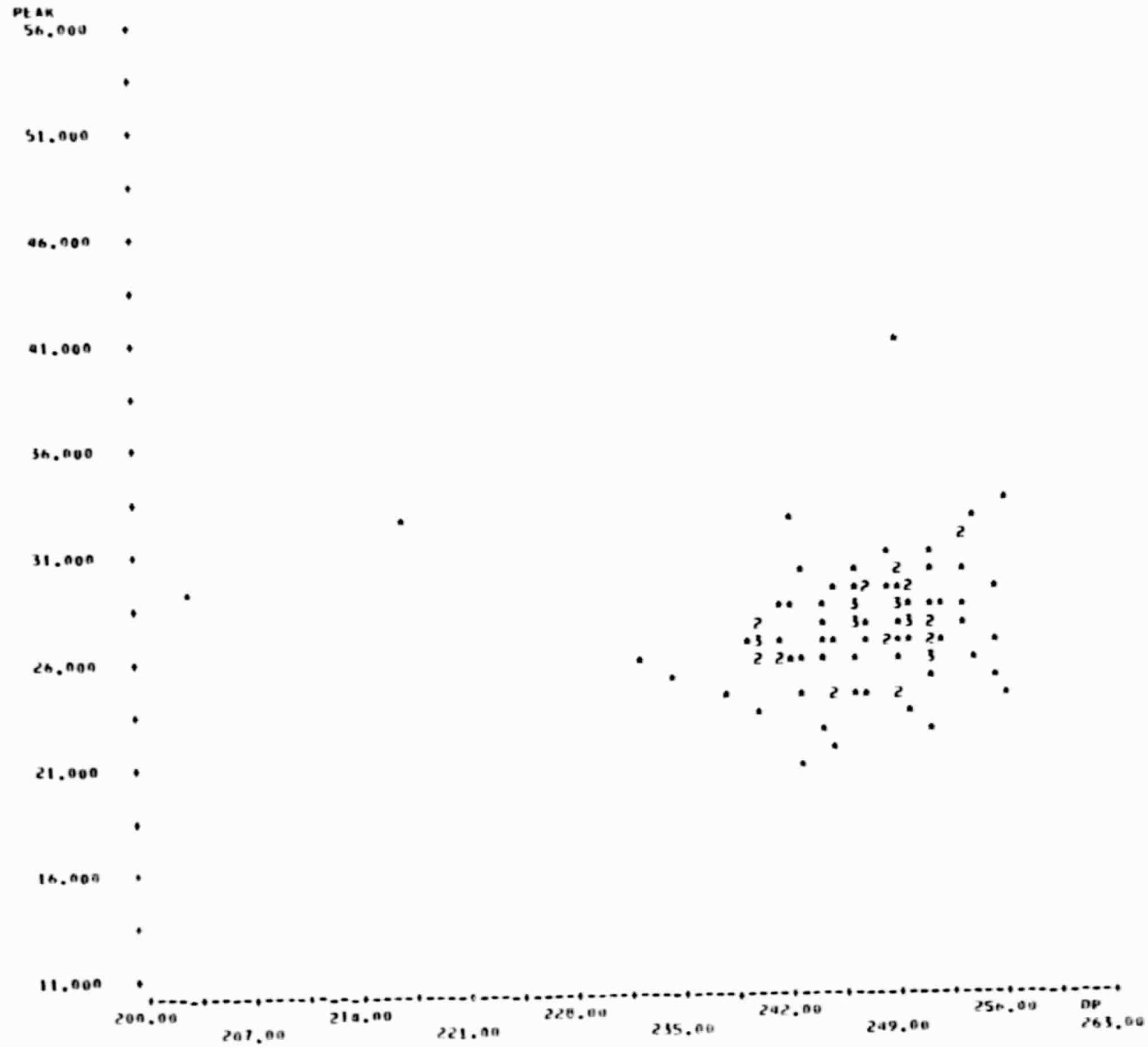
- $\bar{E}$ = average relative error in percent
- Classifications Based on Optimum Linear Discriminants Between Pure Big Blobs

$\bar{E}$	Corn/Soy	All Summer/Other	Well-fit Summer/Other
0-5%	123 852	202	141
	202 853	800	202
	800 877	832	842
	842 881	842	852
		853	853
			881
5-10%		123	205
		205	800
		877	
		881	
10-30%	141	141	123
	205	852	832
	832		877

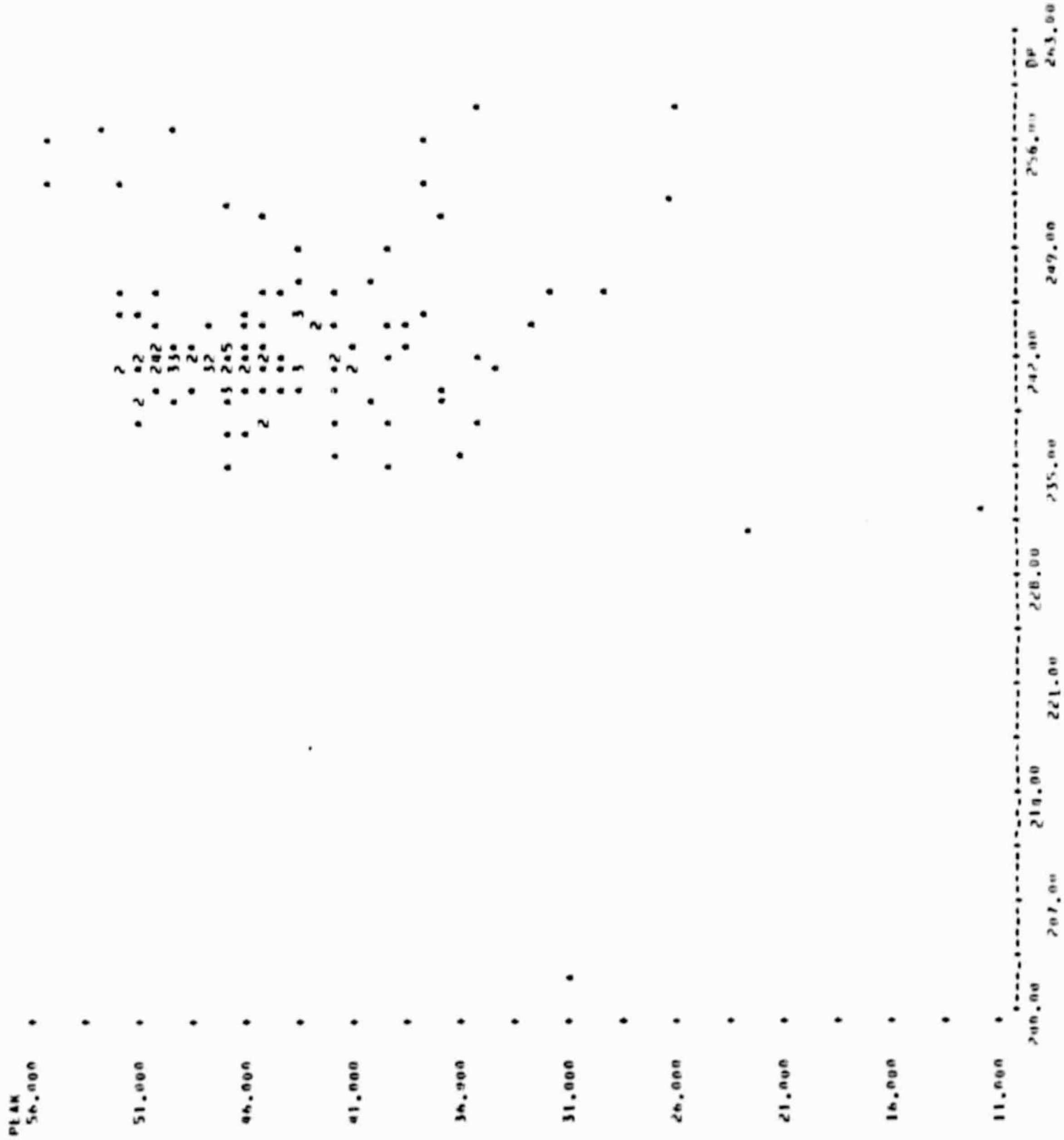
SHORTCOMINGS OF CURRENT PROFILE FITTING TECHNIQUE

- Requires at Least Two Acquisitions on Each Side of Peak During the Growing Season to Give Meaningful Results
- Quality of Results is Dependent on Timeliness of Acquisitions
- Cannot Adjust Itself to Abnormal Conditions (e.g., stress)
- May Require Additional Information to Separate "Well-Fit" Other from Summer Crops
- Non-linear Regression Algorithm Requires Substantial Computer Resources

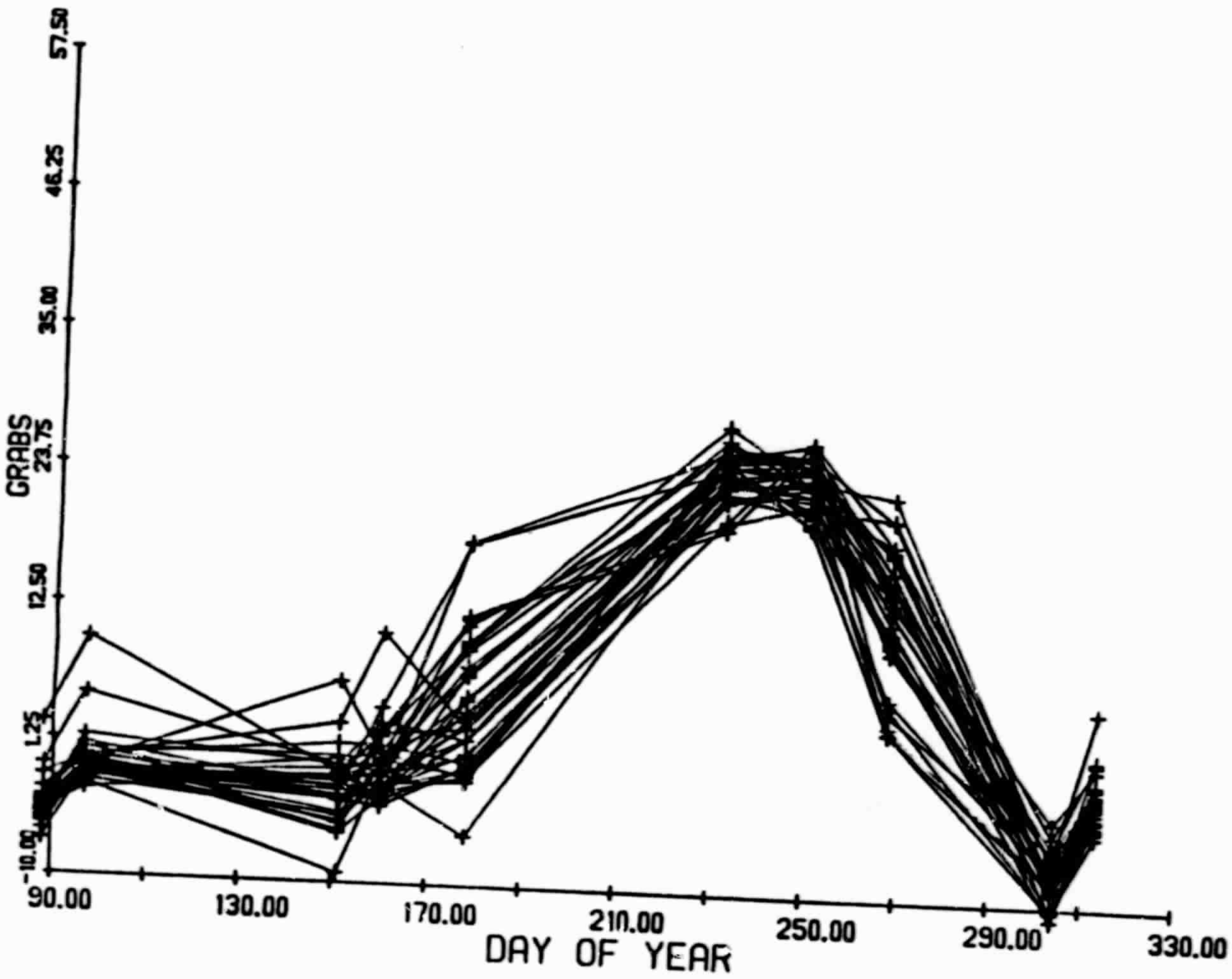
A (Peak) VS. DP FOR CORN BLOBS (SEGMENT 853)



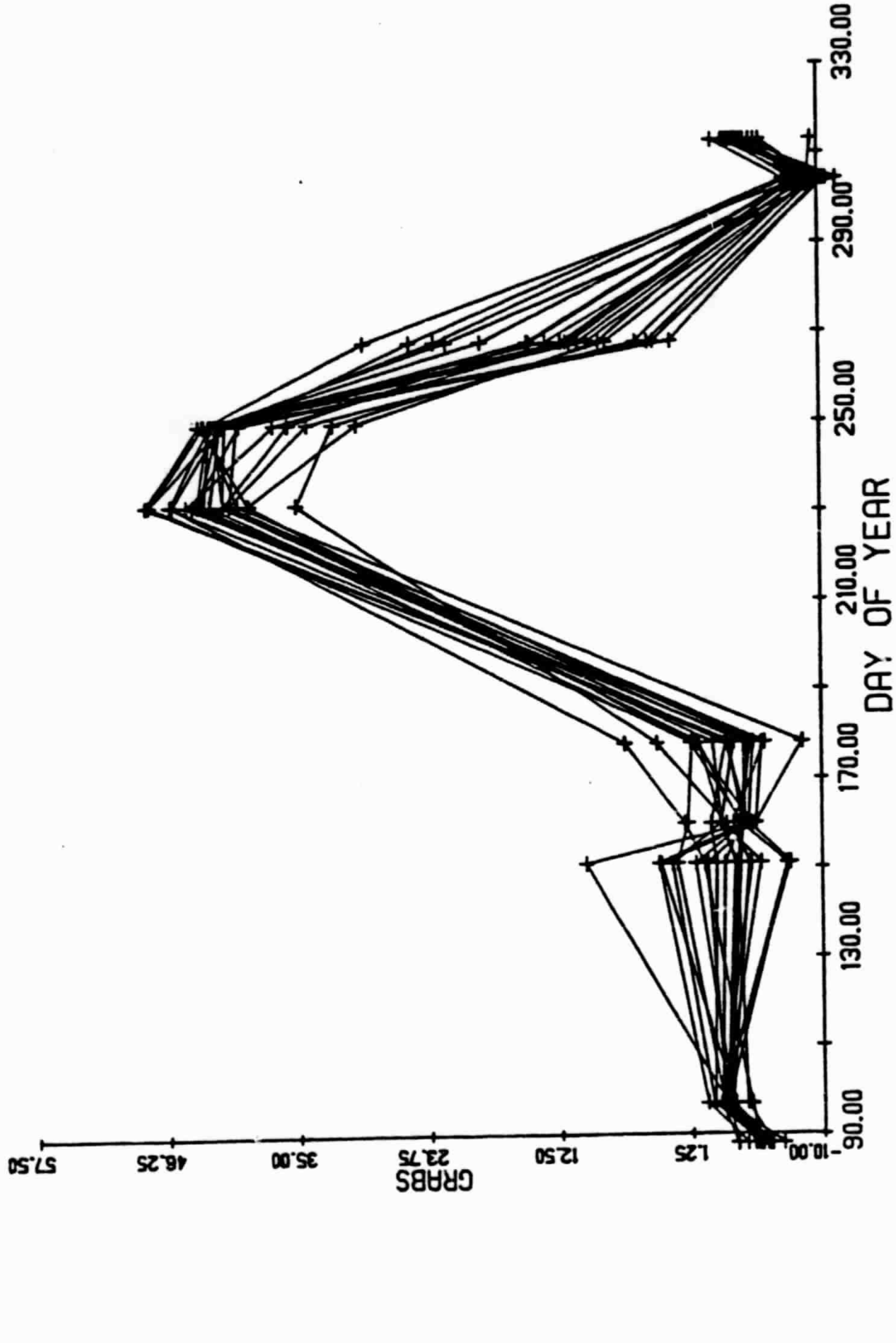
A (Peak) VS. DP FOR SOY BLOBS (SEGMENT 853)



LINE-SEGMENT PROFILES OF SAMPLED CORN BLOBS (SEGMENT 853)



LINE-SEGMENT PROFILES OF SAMPLED SOY BLOBS (SEGMENT 853)



SUMMARY/FUTURE GOALS

- Model Form Used is Well-Fit to a Large Percentage of Crops of Interest While Less than Half of Other Scene Elements are Fit
- Resulting Feature Space Demonstrates Potential Crop Class/Type Separability
- Automatic Classification Seems to Show Promise

FUTURE GOALS INCLUDE:

- Further Improvement in the Separability of Well-Fit Other from Summer Crops
- Determining if Fixed Decision Boundaries in the Feature Space are Viable
- Deriving Area Estimates from the Feature Space Classifications

CORN AND SOYBEAN DISCRIMINATION ACCURACY

'Best Linear Discriminant'

Segment	Best Feature		All Features	
	Corn	Soy	Corn	Soy
123	97.0	88.2	97.8	97.2
141	60.5	81.1	98.7	84.4
202	72.3	80.6	89.2	91.8
205	82.9	70.4	82.9	87.3
800	87.5	89.1	95.4	91.3
832	89.3	74.3	91.1	78.4
842	95.3	95.7	97.7	95.7
843	99.0	91.6	96.0	93.9
853	97.0	93.4	97.0	95.0
877	93.5	87.7	98.4	93.2
881	98.3	80.0	98.3	92.0
Ave	$\boxed{89.3}$	$\boxed{84.7}$	$\boxed{94.8}$	$\boxed{90.9}$

BACKGROUND

- Research and Development of Profile Fitting and Feature Extraction Techniques Have Been Developed at ERIM Through the Supporting Research Project

- The Application and Development of These Techniques as well as Others like Bahdwar Techniques, to Corn and Soybean Area Estimation is Undertaken by the ERIM/UCB Consortium Through the Foreign Commodity Production Forecasting Project